THE INFLUENCE OF BODILY POSTURE ON MENTAL ACTIVITIES

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ARCHIVES OF PSYCHOLOGY

EDITED BY R. S. WOODWORTH

NO. 6, OCTOBER, 1907

Columbia Contributions to Philosophy and Psychology, Vol. XVI, No. 2

NEW YORK

THE SCIENCE PRESS

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CHAPTER I

INTRODUCTION

A thorough consideration of the circulation of the blood in its relation to mental states reveals the fact that slight disturbances in the functioning of the circulatory organs may quite seriously affect consciousness. Blood in the brain of the requisite purity and rapidity of flow seems quite essential to normal consciousness. The lack of proper stimulation by a sufficient quantity of oxygenated blood will produce mental stupidity and coma. Any derangement of the functions of those organs of the body which in any way aid in contributing pure blood to the brain, may be said indirectly to affect mental states. All modern writers upon hygiene insist that for students to do the best work in school, pure air and plenty of exercise are essential, not only for health, but for efficiency in thinking. Seats and desks must be comfortable, and of the proper shape and height to keep the body in a position suitable for normal circulation of the blood and breathing. If either are impaired, the attentive powers are distracted and mental conditions become less efficient.

Since this treatise deals with a comparison of mental activity in the horizontal and vertical positions of the body, and mental activities seem so dependent upon proper blood supply to the brain, it becomes evident that the problem must be considered very largely in its physiological bearings. If it can be shown that in these two positions of the body there are marked physiological differences—differences of blood supply to the brain; differences in heart action, both as to rapidity and force; differences in the breathing reflexes; differences in the condition of the musculature; differences in abdominal pressure; and differences in the vaso-motor activity for the proper distribution of blood to the various parts of the body—then we are led to a consideration of the present problem, whether there are differences in mental activities also.

The problem has been attacked previously in no thoroughly systematic manner. The chapter on the literature will indicate that the physiological phases of bodily posture have been studied, but no systematic work has been done upon the psychological differences, and there is little indication that the physiological differences even suggest a comparative psychological examination. The present research includes an experimental study of mental processes in the horizontal and vertical positions only, but the results here attained seem to indicate a fruitful field of research in other directions. For example, it would be interesting to know whether walking or sitting is more conducive to good thinking, and what individual differences would be found. Many

individuals state that they can think better while walking, but this could be tested under laboratory conditions. Then there are indications that one falls into habitual postures through a sort of selective process, gradually finding the one in which he feels that he can do the best mental work. It would be interesting to test such individuals and determine whether such positions are really conducive to better thought, or whether in some other position they will not do equally well.

It will be noted in the experimental chapters that individuals vary considerably in all the tests made. However, the results in most instances seem to conform to those we would normally expect from a theoretical consideration of physiological conditions. Yet this is not always the case.

For the most part, the literature of the subject will be discussed in Chapter II, though occasionally it may be necessary to make reference to other investigators in the succeeding chapters. The methods and apparatus employed in the experimental work will be discussed usually in the chapter in which the tests and results are recorded.

CHAPTER II

LITERATURE

The psychology of bodily position has been little studied experimentally. There is no doubt that many writers have considered, as of some significance, the fact that individuals vary in bodily posture in executing many of the ordinary tasks; but the trouble has not been undertaken to subject individuals to accurate tests and find out whether there is a favorable position for certain types of mental life or not. Introspective evidence is not lacking that certain bodily postures are favorable for particular mental tasks, but psychologists are skeptical as to the validity of the mere introspective evidence without corroborative testimony from the experimental laboratory. Consequently, the great portion of the literature will bear rather upon the physiological aspects of the question than the psychological.

Lauder-Brunton[1] discusses at some length the effect which gravity has upon the diaphragmatic action, and the outward pressure upon the abdominal wall. In the upright posture, the diaphragm moves vertically, but the abdominal walls and intestines move in a horizontal plane. Consequently, in this position there is no lifting work for the diaphragm to do. When a man is lying on his back, however, the case is quite different. During inspiration, the diaphragm encroaches upon the intestines, and has actually to exert enough force to raise them and also the abdominal walls. Thus the recumbent posture may be of advantage in diseases in which the weight of the intestines will drive the diaphragm back up into the thorax and aid expiration. In heart and lung diseases,[2] however, the opposite seems to be the case. Most patients have a desire to sit up in bed, or even to walk about slowly. Leonard Hill points out in a rather significant way, also, that it is possible to give an accurate diagnosis of many diseases by studying the posture of the patient. Even mental diseases of the various types have their peculiar bodily postures. Also in perfectly normal individuals, psychic states more or less influence the bodily posture, while weather conditions,[3] temperature, humidity, wind, etc., have not only been shown to effect the posture, but also to have striking causal relations to very significant acts of will. Lauder-Brunton also points out that the varying types of emotion have their individually characteristic bodily postures, and this posture seems to be

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[1] Lauder-Brunton, *Popular Science Monthly*, 42, 33.

[2] Leonard Hill, *Cerebral Circulation*, London, 1896, p. 78.

[3] Dexter, "Conduct and the Weather," *Psychological Review*, Monograph Supplement, No. 10, 1899.

a real expression of the emotion. James[1] illustrates the same point by saying: "Whistling to keep up courage is no mere figure of speech. On the other hand, sit all day in a moping posture, sigh, and reply to everything with a dismal voice, and your melancholy lingers. There is no more valuable precept in moral education than this, as all who have experience know: if we wish to conquer undesirable emotional tendencies in ourselves, we must assiduously, and, in the first instance, cold-bloodedly, go through the outward movements of those contrary dispositions which we prefer to cultivate."

Again Lauder-Brunton shows in a remarkable passage how bodily posture seems to have great influence upon the free play of ideas. "An experience of my own once showed me how dependent the brain is upon the supply of blood. I was called upon one night, after a long day's work, to write an article immediately. I sat down with pen, and ink, and paper, but not a single idea came into my head, not a single word could I write. Lying back, I soliloquized: 'the brain is the same as it was yesterday, and it worked then: why will it not work today?' Then it occurred to me that I was not so tired the day before, and probably the circulation was a little brisker than to-day. I next thought of the various experiments on the connection between the cerebral circulation and mental activity, and I concluded that if the blood would not come to the brain, the best thing would be to bring the brain down to the blood. I laid my head flat upon the table, and at once my ideas began to flow, and my pen began to run across the paper. I thought, 'I am getting on so well now I may sit up,' but the moment I raised my head, the mind became an utter blank; so I put my head down again flat upon the table and finished my article in that position."

In President Baker's[2] address before the Anthropological Section of the American Association for the Advancement of Science, in 1890, he calls attention to the remarkable changes that have taken place in the human body as it gradually, through the long processes of evolution, assumed the upright position. Since gravity must play a very important part in the visceral and circulatory organs, therefore any change in the equilibrium must necessarily cause some disturbance in organic functions. These disturbances will necessarily weaken the animal and will interfere with its assuming the upright posture. There is of necessity, then, a long period of struggle, both mental and physical in which the organic structures of the body are gradually adapting themselves to the new position. There is much evidence that this struggle is still going on, and that the adaptation is still far from complete. He enters into a rather extensive description of various organs which have been modified, and are still being modified, in order to

[1] James, *Principles of Psychology*, Vol. II., p. 463.

[2] Frank Baker, *The Ascent of Man*, Amer. Asso. for the Adv. of Sc., 1890.

become perfectly adapted to a vertical posture. The pelvis, which forms the support for the internal organs, has become more disc-like and thicker and the opening through it has become much smaller. These changes are more pronounced in the female than in the male, since it must bear the weight of the pregnant uterus. Indeed it has become a sort of compromise between an arrangement of great strength for support, and ease in child delivery. Since the head of the child was greatly increased with the vertical posture, childbirth became much more difficult, and the struggle has been terrific. Woman's entire physique shows signs of very many physical changes, and in no animal is there such a difference in the sexes as in man and woman. Hernia is another sign of imperfect adaptation. In quadrupeds the weight of the abdominal organs is swung from the spine by the tunica abdominalis. In man this has entirely disappeared except in the groin, and here it frequently gives way, causing rupture. Uterine displacements are almost unknown in the horizontal posture, but are among the most common sexual complaints of the vertical female. The "knee and elbow" treatment of this malady, which is decidedly quadrupedal in nature, is suggestive of the imperfect adjustment to the vertical posture. Stone[1] in the bladder is unknown to quadrupedal animals because all sediment is easily drained off through the urethra. President Baker quotes from Dr. Erasmus Darwin as follows: "It has been supposed by some that all mankind were formerly quadrupeds as well as hermaphrodites, and that some parts of the body are not yet so convenient to an erect posture as to a horizontal one. As the fundus of the bladder in an erect posture is not exactly over the insertion of the urethra, whence it is seldom completely evacuated, and thus renders mankind more subject to the stone than if he had preserved his horizontality." The appendix is a vestigial organ and only functioned far down the biological scale below man. In quadrupeds it is so placed that gravity aids in freeing it from foecal accumulations, and it is thus seldom diseased. The liver, in quadrupeds, hangs from the spine, but in man it depends from the diaphragm, which in turn has attachments with the fibrous coverings of the heart, and these in turn are continuous with the fascia of the neck, so that in reality, the liver hangs suspended from the upper thorax. This decreases the degree of action of the diaphragm, confines the lungs more closely, and must interfere somewhat with the action of the blood, and consequently impairs the vertical animal's power to endure rapid muscular exercise. There are also many difficulties in the circulation of the blood in the vertical animal, such as the raising of the blood through the ascending vena-cava, whence comes congestion of the liver, and cardiac dropsy. Then in the descending vena-cava there is a tendency

[1] Dr. Erasmus Darwin, *Temple of Nature*, Canto II. (Note), Jan. 1, 1802.

for the blood to drop too rapidly, producing syncope. Valves of the circulatory system are arranged for the horizontal position of the body, and not the vertical. They are wholly lacking in some of the more important of the vertical trunks, yet are found in many of the horizontal veins where they are not at all needed.

Probably the most careful student of the physiological effects of bodily posture is Leonard Hill,[1] the great English physiologist. In his chapter in Schäfer's "Text-Book of Physiology," he compares the whole circulatory system to a network of distensible tubes, having a pump in the midst of the system to force the blood in both directions—upward against gravity and downward with gravity. By the valves in the veins, the tonicity of the arterioles, and the muscles of the abdominal walls, the circulation is supposedly efficient with the body in any position, save the head down. This is not actually true, as will be shown in some of the experimental chapters, for many individuals are not endowed with the vaso-motor mechanism which renders the compensation for gravity perfect. However, with a perfectly normal individual, the mechanism is adequate, and the circulation will be efficient with the body in any of the various positions ordinarily assumed.

Leonard Hill[2] shows that the great splanchnic area forms a sort of resistance box of the circulation. If the vessels here are contracted, the blood must make its way to the muscles and brain and other parts of the body. If these vessels are dilated, the blood lodges there, and he claims that they are capacious enough when fully distended to hold all the blood of the body. He affixed a dog to a board which could be swung around an axis, throwing the animal alternately in the horizontal and vertical feet-down positions, and then by opening the jugular and carotid artery and cannulae connected with manometers, he was able to read the arterial and venous pressure in the two positions of the body. Dropping the animal into the vertical feet-down posture, the arterial pressure falls to a slight extent, and then rises to the normal level. The hydrostatic effect is here practically nihil because of the integrity of both the vaso-motor center and the respiratory pump. By cutting the splanchnic nerves, the arterial pressure falls very low in the vertical feet-down posture, which shows that gravity becomes of vital importance when the vaso-motor tone of the splanchnic area is destroyed. If, in addition, the respiratory pump is thrown out of gear, the circulation becomes impossible.

This same writer[3] has shown that a rise in the arterial pressure produces an increased velocity of blood in the brain. In great rises of

[1] Leonard Hill, "Effect of Change of Posture on Circulation," *Schäfer's Text-Book of Physiology*, Vol. II, p. 90.

[2] Leonard Hill, *British Medical Journal*, 1897, Vol. 1, p. 959.

[3] Leonard Hill, *Cerebral Circulation*, London, 1896, p. 78.

pressure by absinthe, he shows that the outflow of blood from the torcular increased from twice to six times. And the metabolism of the brain was found to be very little as compared to that of the muscles. The practice of wearing belts for weakness and after parturition has a real physiological significance, since it increases the output of blood and the pressure of same in the brain. In this connection, he refers to the significant fact that some people lose their memory[1] in the vertical posture and regain it upon recumbency. Also some individuals do better mental work when in the horizontal position. The Rabelaisian effects of fear, manifested by soldiers before battles, may be due to the splanchnic dilation of the blood vessels and the blood rushing to the abdomen. Every stimulus that affects the nervous system affects the vaso-motor centers, and thus has an effect upon the cerebral circulation. A pleasant emotion raises the blood pressure, and an unpleasant one lowers it. The vaso-motor is a sort of protective arrangement whereby blood can be drawn from the abdomen to supply the brain. When a certain stimulus demands cerebral response, the splanchnic area constricts, and blood is driven rapidly through the brain. With this mechanism slightly out of order, change in the posture would produce differences in blood supply to the brain, and we would thus expect to find slight differences in mental states.

The experiments of Erlanger and Hooker[2] agree very closely with those of Hill, and show that the changes in the circulation of the blood, due to changes in posture are very largely hydrostatic, and in the majority of cases not at all due to the inefficency of the vaso-motor mechanism. They show by the use of the von Kries tachygraph that the acceleration of blood flow per heart-beat is greatest in the recumbent posture and smallest in the vertical posture. These results, together with those of Hill, would suggest a possible theory for greater intellectuality in the recumbent posture. Their research shows also that posture has a marked effect on the character of the urine, chlorides, phosphates, and nitrogen being much smaller in the standing than in the recumbent posture.

Kiesow[3] has investigated the blood pressure of a large number of individuals, and has found that the position of the body is a very important factor. In eighty per cent. of the subjects, the pressure is greatest in the vertical posture and least in the recumbent posture. Violent gymnastic exercise increases the pressure from 70 or 80 to 100 or 110. Massage increases the pressure from 60 to 90. The pressure keeps up for about fifteen minutes and then returns to the normal. Coffee will increase the blood pressure from 10 to 15 points, which

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[1] Leonard Hill, *Cerebral Circulation*, London, 1896, p. 112.

[2] Erlanger and Hooker, *Amer. Jour. of Physiology*, Vol. X, 1903-4.

[3] Kiesow, *Arch. Ital. de Biol.*, Vol. XXIII, p. 198, 1895.

continues for about an hour. In his series of experiments to determine whether intellectual effort and sustained attention produced changes in the blood pressure, he reaches the conclusion that it is only when they verge into feelings and psychic disturbances of some sort that we can detect changes in blood pressure as a result. Of course if deep psychosis produces change in blood pressure, we might infer that the reverse would also be true, and if posture has influence in the change of blood pressure and rapidity of flow, it would indirectly affect the mental life.

One of the most exhaustive treatises on blood pressure is that of Janeway, "Clinical Study of Blood Pressure," 1904. He brings together a great deal of the clinical evidence from numerous sources upon the subject, and throws some light upon the present problem. He shows that blood pressure depends upon four separate and distinct things, *viz.*, the energy of the heart, the peripheral resistance, the elasticity of the arterial walls, and the volume of the circulating fluid. Hill and others would add to these, the bodily posture. The nerves[1] which have greatest effect on the general blood pressure are those which are distributed to the splanchnic region. So long as these nerves are intact, splanchnic circulation can usually compensate for the most extreme narrowing of the rest of the arterial tree, but if a section is made through them the arterial pressure immediately falls. Bezold,[2] in his researches in Leipzig, reached similar conclusions. If, also, the vasomotor centers themselves are impaired in their activity, the pressure falls when the body is changed from the horizontal to the vertical posture.

Janeway[3] shows that the volume of blood in the body is small when compared with the full capacity of the veins, arteries, and capillaries. Some of the vessels are nearly empty a good portion of the time, and distribution in the necessary parts is effected by the tonus of the muscles in the walls of the vessels. If the cord is destroyed, the blood all flows quickly into the veins and the animal bleeds to death inwardly. An amount of fluid[4] greater than the total blood volume of the body has been infused into the veins and blood-vessels, without raising the pressure above a point frequently reached in normal life. Pawlow, quoted by Janeway on p. 26, put immense quantities of bouillon into the blood vessels of a dog without any rise in the pressure. These experiments show that pressure does not de-

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[1] Ludwig und Cyon, *Bericht d. Sach. Gesellsch. d. Wissensch. Math. Phys. Cl.* 1866.

[2] Bezold, *Untersuchungen über die Innervation d. Herzens*, pp. 223-229, 1863.

[3] Janeway, *Clinical Study of Blood Pressure*, p. 25, 1904.

[4] Worm-Mullerm, *Bericht d. Sach. Gesellsch d. Wissensch. Math. Phys. Cl.*, 1873, pp. 573-664.

pend so much upon the quantity of blood in the vessels, but upon the position of the body and the mechanism for changing the calibre of the vessels to drive the blood to the part of the body where it is needed.

Keith,[1] in the *Lancet* for March, 1903, discusses the "Nature and Anatomy of Enteroptosis," and indirectly throws some little light on the importance of posture and the effects of gravity upon some of the vital organs. The writer endeavors to show that enteroptosis is a disease which is brought about by a lack, on the part of the muscles of the abdominal wall, to resist the effects of gravity upon the organs of the thorax and abdominal region. It is a condition found only in animals of the upright posture, and most frequently in man. He says that the thoracic and abdominal organs are poised between the muscles of inspiration and expiration. This poise between the two cavities for most individuals remains about constant throughout life. Sometimes, however, the muscles of inspiration get the upper hand, and the viscera of the thorax and abdomen become displaced, resulting in what is called enteroptosis. It may affect particularly any one organ, or it may affect a whole group, bearing strongly down into the abdomen, the stomach, liver, spleen, and intestines. Post-mortem examinations show that these organs vary as much as two or three inches from the normal position, causing intense pain and completely changing the mental and physical life of the individual.

There is likewise an affection, known as Glenard's[2] disease, usually met with in women, due to repeated pregnancies, or undue exertion or injuries. It is a general falling of the abdominal organs due to gravity. The transverse colon is the first to descend, and then the stomach is drawn down so that the pylorus is greatly compressed and does not allow the food to pass freely. The whole mass of the small intestines becomes prolapsed and the abdomen becomes distended. Liver and kidneys become loose and are described as floating. The patient suffers greatly and can only be relieved by assuming the horizontal position or wearing tight bandages around the abdomen. This disease has a great effect on the mental life also, in many instances producing moroseness and melancholy. Such results would be expected from so great a displacement of the vital organs.

Kornfeld[3] found that in practically all kinds of physical exercise, with the body in various positions, the blood pressure rises above the normal at first, and then there is a sudden falling off. Within one minute after the ceasing of the exercise, the pressure is again normal. He found also that exercises which required great attention made the pressure go higher. A melody on a violin, when the subject was trying

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[1] Keith, "The Nature and Anatomy of Enteroptosis," *Lancet*, March, 1903.

[2] Treves, "Treatment of Glenard's Disease," *Brit. Med. Journal*, Vol. 1, 1896.

[3] Kornfeld, *Wein. Med. Blat.*, Vol. XXII, 1899.

to recognize it, caused the blood pressure to rise from 110 mm. to 150 mm., but as soon as the melody was recognized the pressure fell to 130 mm. This experiment shows, possibly as well as any on record, that mental states are in some intimate manner associated with blood pressure to the brain. If so, then posture, which has been shown to have great influence on blood pressure, will also have some effect on one's mental life.

It has been shown[1] that upon the child assuming the upright posture, several changes in the spine take place in order to counteract the effects of gravity. At first a sharp forward curve develops in the lower lumbar region, continued up into the dorsum. The back thus becomes hollowed. Gradually a compensating curve develops in the dorsal region, forming a well marked backward curve. Then a third develops later in the cervical region which is more closely akin to the lumbar. During the greater part of the time that these curves are forming, the child is in school. An examination of the boys of the Montreal High School reveals the fact that 23 per cent. of them had lowered shoulders, and 30 per cent. the "gorilla type" of posture when standing. About 14 per cent. of all college students examined at McGill University have similar deformities. It cannot be safely asserted without actual testing that these deformities bring about correlative mental defects, but since they are spinal defects, we would expect from them some derangement of the mental life. The posture of children in school, while sitting and standing, should be watched very carefully, and any incipient defects carefully corrected. Posture is not only important from the standpoint of the child's health and activity, but because it furnishes us indications of habitual modes of thought in children. A thorough study of the posture of children would reveal many means of building up the physical health. Rowe[2] says that in standing rather than sitting we see the habitual modes of thought of the student finding expression. The erect head is the expression of self-confidence and conscious power. The drooping head and the sunken chest is the expression of weakness.

One of the best contributions to the study of posture in its relations to blood pressure and heart-beat is that by Crampton,[3] Assistant Superintendent of Physical Training in the New York City Schools. By means of a table correlating heart-beat and blood pressure in the horizontal and vertical positions of the body, he determines physical condition. The index to physical condition he asserts to be the

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[1] McKenzie, "Influence of School Life on the Curvature of the Spine," *N. E. A. Report*, p. 939, 1898.

[2] Rowe, *Physical Nature of the Child*, Chapter X.

[3] Crampton, "A Test of Condition: Preliminary Report," *Medical News*, Sept., 1905.

efficiency of the vaso-motor mechanism in controlling the blood supply to the splanchnic area. This is shown by the table, and individuals are divided into nine groups according to the changes in heart-beat and blood pressure when elevated from the horizontal to the vertical position. I shall refer to this table again in my experimental work where I have attempted to correlate mental efficiency with physical condition according to his standards.

N. Vaschide,[1] in 1904, made a series of experiments in tactile perception by the use of the aesthesiometers under standard conditions on consecutive days. His subjects were naked so as to be free from all pressure of the clothing. Then the same experiments were repeated with conditions such as to necessitate marked circulatory modifications. Bands were tied about the arms and neck and limbs so as to bring about congestion in certain parts. The position of the body was varied considerably also to produce congestion and free circulation. His results are as follows: Tactile sensibility varies under the influence of change of position and freedom of the circulation. Fineness of discrimination depends immediately upon the efficiency and strength of circulation. By a mere shift of the bodily position so as to bring about a different condition of circulation, measurable differences of sensation are provoked. He emphasizes the fact that a powerful and constant flow of blood increases the sensibility. Anemia produces a diminution of sensation qualities, as does also congestion of blood. Nervous diseases and supersensitiveness are frequently due to blood pressure in certain parts of the body. Any member spontaneously flooded with blood becomes more sensitive. Vaschide insists that all tactile senses need revision according to these principles.

All the literature upon the subject of blood pressure and distribution of blood to all parts of the body, indicates clearly that bodily posture has a very potent influence in determining the same. And since consciousness depends for its normal state upon the proper circulation of the blood to the brain, we are justified in assuming that in all individuals, posture alone will produce measurable variations in the various senses, and even in the deeper processes, such as memory, judgment, and reasoning. The experimental part of this dissertation will undertake to measure these variations as found by changing the bodily posture of the subject, and at the same time measuring the variability in the psychic processes.

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[1] Vaschide, "Les rapports de la circulation sanguine et la mesure de la sensibilite tactile," *C. R. Acad. D. Sci.*, Vol. 139, pp. 486-488, 1904.

CHAPTER III

LETTERS FROM WELL-KNOWN INDIVIDUALS STATING THEIR FAVORITE POSITION OF THE BODY FOR THE BEST INTELLECTUAL WORK

In the beginning of this research, it seemed quite essential to know whether individuals have favorite positions and attitudes of the body in which they habitually do their intellectual work, and also, if possible, to find out how these came to be assumed, whether by mere chance, or whether, by gradual experimentation and elimination of unsatisfactory postures, a fixed one was assumed in which the best work could be accomplished. The writer was convinced from observation of students in classrooms and study rooms, and from the postures of children in the kindergarten and lower grades of the public schools, that great individual differences would be found. It was apparent that these differences were not mere chance variations, but seemed rather to be due to a process of selection by which that bodily position is gradually assumed, which conduces to the easiest flow of ideas. In order to investigate these various points, several hundred letters were written to men who have gained eminence in at least fifteen different walks of life. A personal letter was written to each individual, stating the purpose of the research, and asking a few questions which could be easily and quickly answered. Some three hundred and fifty responses came as a result of this inquiry, which, in the opinion of the writer, give rather conclusive evidence that mental states are somewhat dependent upon bodily position, and that most individuals who do highly specialized intellectual labor find that there is some one bodily posture which will very greatly facilitate their work.

A few of these letters are given here to show certain tendencies which seem to prevail, and to throw some light on the prominent part which posture does seem to play in our best thinking.

The following letter is from a man who has for years been prominent in politics in the West, has been in Congress, and was twice in succession governor of a state.

"Dear Sir:—Your letter of inquiry concerning the position of my body when I do my best thinking, interested me, for I have often wondered why my ideas always seem clearer after I go to bed at night. I have formed the habit for many years of spending an hour or more doing some careful thinking immediately after I retire. If I am to deliver an address, I think out my speech in bed, generally just the night before. You ask me to state how I got into this habit. I think it dates back to my school days when I invariably solved my difficult mathematical problems after retiring. Sometimes when I arose in the morning, I had forgotten the solution, and could not get it during the day, but was sure to work it out the next night again."

I may say that this is a very general type of letter. A number of individuals refer to the solution of problems in mathematics as easier in the horizontal position of the body, and say that they frequently reserve the most difficult work until after they retire. In conversing with individuals, the writer has found that these are not isolated cases but that practically every one has some special position of the body which apparently must be assumed to get the best mental results, and it is surprising how many have referred to doing the most difficult mental tasks in bed.

The following letter was received from a journalist in the Middle West, whose editorials are without doubt of the very first rank. He is also a man of great political influence, and a first-class orator.

"My Dear Sir:—In reply to your inquiry, will say that I can do my best thinking while lying down. I have in my office a divan upon which I recline when thinking out anything particularly difficult, for I have found that ideas come more easily, and are more easily clothed in appropriate words in this position."

From this letter, I assume that the writer dictates to his stenographer, and that in this instance we have illustrated that the horizontal position not only conduces to clear thinking and clearer ideas, ideas that better fit into the apperceptional mass of the editor, but also that it facilitates the physiological expression of these ideas in appropriate language.

Another letter describes a posture which has decidedly physiological advantages from the standpoint of the circulation of the blood. It reads as follows:

"Dear Sir:—I wonder what psychologists will investigate next. Your queries cause me to wonder what you are about. The posture that I assume for literary work will amuse you. I have written the greater portion of all my books while lying on the floor on my belly."

This writer's name is almost a household word in America. Few men stand higher in the literary world to-day, and every boy has read his books with pleasure.

The position which this writer assumes brings the pressure of the weight of the body upon the splanchnic area and serves to keep the blood squeezed from the capacious veins there, and distributed to other parts of the body. This position[1] would not only favor the vasomotor mechanism for the compensation for gravity, but would permit of no congestion of this region whatever and keep the brain stimulated with blood. These effects might more than compensate for the inconveniences of the position for writing. And indeed, chirography,

[1] Leonard Hill, "Experiments on Blood Pressure," *Brit. Med. Jour.*, 1897, Vol. I.

judging from the manuscripts themselves, scarcely enters into the consciousness of writers.

Another letter from an American psychologist may be of interest as bearing directly upon this same subject of the position of the body when doing mental work.

"Sir: I have never considered the position of the body in mental work as of very much importance; however, I am free to confess that much of my best thinking has been done while reclining. It is my custom in my study to think out many problems while lying on a couch on my right side with my right elbow under my head. I cannot give you the genesis of this position, though I think it dates back into childhood."

This position is rather peculiar, save that it is practically horizontal. No other individual describes this exact position. It might be explained simply as the most convenient one in his particular study. The couch may be so placed with reference to his study table that it is easy to fall over on it and assume a horizontal position on the right side.

From the evidence in the letters received, there is another type of position much used in intellectual work which may be designated as semi-horizontal. It is usually described as "easy." The feet are placed upon a table or other high object, the chair being forced back upon the two hind legs, usually leaning against the wall or other support. This posture, I have noted many times, is a favorite one with students in dormitories, and in their own private rooms everywhere. Thirty-five out of eighty-one students visited in Hartley Hall, Columbia University, for observation of the position in which they were engaged in study, were found to have their feet upon a table or chair or some other object which elevated them very much and gave the body what might be called a semi-horizontal position. Morris chairs are a special device invented to bring about this particular position.

The following letters will indicate a very pronounced tendency among eminent individuals to assume this position in doing intellectual work.

"Dear Sir: I will say that I can do my best thinking in my own quiet study, with my feet thrown loosely up over the corner of my table, or possibly even higher. I have been accustomed to this position for years, and even write so. My writing is done chiefly on a large pine board which I hold across my lap."

"Dear Sir: In answer to your inquiry will say that I sometimes recline on a couch while I write, but more frequently sit in a large, low-bottomed chair with my feet either upon another chair, or upon the table in front of me. I can assign no special reason for taking this position except that it seems perfectly comfortable, and this fact alone seems conducive to good thinking."

"My Dear Sir: The greater part of my writing has been done in a large arm chair with a very slanting back. Across the arms I usually place a large board, forming a sort of lean back table right in front of me. My feet are then placed high, so as to give me almost a reclining posture, and yet a most convenient position for writing."

The following letter is from a man of national reputation as a writer of negro dialect. In addressing him, I asked him if there was any motor tendency on his part to assume typical negro postures while attempting to depict minutely certain characters and types. His answer throws a little light on this interesting question in addition to the one before us.

"My Dear Sir: In reply to your inquiry concerning my bodily position while writing my negro stories, will say that it varies somewhat. In the summer time, I write a great deal out of doors, lying upon the lawn, or anywhere I can have an opportunity to watch one or two of my servants work, and hear their conversation. I generally have them doing odd jobs near me for purposes of which they are totally ignorant. In my study, I usually sit in a low chair with my feet high, and some means of writing across my lap, or on a small table at my side. I do not find that I have a tendency to make any bodily movements of negroes that I wish to describe but I try to see in my imagination very clearly every movement and attitude described."

Of course we do not have here the testimony of a psychologist as to these images. It may be that if instruments for recording delicate movements were attached to this writer, it would be found that the imagery had a background in much movement.

One other letter of the type belonging to this group is sufficient to show the general tendency to a semi-horizontal posture.

"Dear Sir: I can do my best thinking in a Morris chair with the back at a low angle and my feet on a high stool. This position has now become habitual and I involuntarily drop into it, though it has been learned in the past two years. I find it the most comfortable and the most conducive to an easy flow of ideas. I formerly worked, sitting at my study table."

About sixty-five per cent. of all letters received conform pretty clearly to these two types. This investigation seems to indicate rather definitely that a large number of writers, men of science, ministers, statesmen, and those who have become distinguished in various lines, chose practically the horizontal position for their most careful intellectual work. The remainder of the letters is difficult to classify. Quite a large number state that they do their best and most careful thinking during some solitary walk. Many say that they must get down over their work at a table, and seem to indicate that there is some efficacy in holding the head up with one hand and writing with the other. One says that he must have the temperature of his room about eighty degrees, and must sit at a low table. Some few declare

that the position makes no difference in their mental life so far as they can see. At one time they will recline, at another walk about their room, and at another quietly sit at their study table. Several state that some sort of contact of the hand with various parts of the face or nose, or the stroking of the hair seems to stimulate mental activity. This is nearly always mentioned as being helpful while sitting at a table engaged in study. There are several examples of individuals who seem to arrive at their most original ideas while in bed, and arise to write them down and clothe them in proper language. On the other hand, a few assert that a pleasing thought can be put into the best language only after they retire at night. One minister states that he works over all his material for a sermon at his study table, but puts it into the proper form for delivery while in bed. Another does just the reverse. A poet writes, "No man ever became a poet sitting at a table; he must lounge and dream." There are vast individual differences in this remaining thirty-five per cent. No two seem exactly to agree in a favorite posture, and indeed posture does not seem to influence their mentality to a great extent. There may be counteracting forces in their temperament which overbalance any effect which posture might have. It will be shown later, however, in the experimental portion of this work that posture is a great factor determining efficiency in mental states, even though the subject is not aware of it, and may deny it. A subject may declare introspectively that a certain position is preferable for certain mental tests, and yet show by actual experiment that the opposite position for him is preferable. This, of course, shows that there is little validity in the opinions of the authors of the letters previously quoted, and that such testimony can have little value until it is verified by careful experimentation under laboratory conditions.

CHAPTER IV

DISCRIMINATION OF PITCH

Method.—In this chapter three series of experiments upon the discrimination of pitch will be described. The effort is to determine whether there is a general tendency for individuals to discriminate better in the horizontal or vertical position of the body. The first series of tests was made upon school children of the eighth grade in the public schools, ranging in age from ten to thirteen years. A cot was provided in a quiet room, upon which the children could recline for the tests in the horizontal position. For the vertical they were simply required to stand upright, and at an equal distance from, and the same relative position to, the stimulus. For these tests a mandolin was used, tuned to concert pitch. The A strings were made to vary from each other from two to four vibrations per second, according to the threshold of the subject. At the beginning of the testing of each subject, enough preliminary trials were made to determine the probable threshold, and then this difference was maintained throughout the recorded series for this subject. The A strings tuned in this fashion were used "open" for all subjects, so as to give the same quality of tone. Care was taken also to pick the strings evenly and with the same intensity, and at the same distance from the bridge in all experiments. The instrument used was a Tony Beahl make, having an excellent quality of tone, and easily dampened by the fingers, without giving any unpleasant over-tones or vibrations which would distract the attention. The method used, as in all the tests on the discrimination of pitch, was that of right and wrong cases. One hundred tests in each position were made upon all subjects with the exception of two, who were given one hundred and fifty. The two A strings, tuned as previously explained, were picked, an interval of two seconds intervening, and the subject was asked to say whether the second was higher or lower. If unable to decide, he was asked to guess. The probable error was then determined from the percentage of the right cases by the Fullerton and Cattell[1] table.

In all the experiments on discrimination of pitch the subjects tended to become easily fatigued. In consequence it was necessary to change the posture of the subject quite frequently, in order that the fatigue effects should be distributed equally in the two positions. Generally ten tests were made in one position, and then the subject was changed to the other; if, however, signs of fatigue appeared sooner, the subject was alternated from one position to the other every five experiments.

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[1] Fullerton and Cattell, *On the Perception of Small Differences*, p. 16, 1892.

In this way there was no chance for the constant error of fatigue to enter more strongly in one position than another. The same holds for the practice effects, which were undoubtedly present in a large number of subjects. Similarly, whatever improvements were made by the individual subjects, will be found equally distributed in the two positions, because of the frequent change of posture.

TABLE I

The following table gives the results of tests made on eleven school children for the discrimination of pitch.

Horizontal						Vertical				
Subject	Sex	Δ	Number of experiments	Per cent right	P. E.	Δ	Number of experiments	Per cent right	P. E.	Comparative per cents
G.	Male	3	100	65	5.2	3	100	69	4.0	77%
A.	Female	4	100	82	2.9	4	100	88	2.3	79%
M.	Male	3	100	82	2.2	3	100	76	2.8	127%
S.	Female	3	100	91	1.5	3	100	82	2.2	146%
H.	Male	4	150	79	3.3	4	150	84	2.7	81%
L.	Male	3	100	94	1.3	3	100	91	1.5	115%
M. G.	Female	3	100	75	3.0	3	100	82	2.2	73%
H. T.	Female	4	100	60	10.6	4	100	67	6.0	57%
B.	Male	3	150	79	2.5	3	150	74	3.1	124%
G. S.	Male	4	100	81	3.0	4	100	90	2.1	70%
H.	Female	2	100	68	2.9	2	100	73	2.2	76%
				M. 77.8 M.V. 7.8	M. 3.5 M.V. 1.6			M. 79.6 M.V 7.4	M. 2.8 M.V .8	M. 93% M.V. 25%

Explanation of Table I.—All of the tables in discrimination of pitch are somewhat alike, and an explanation of Table I will clarify all. The results to the left of the middle line of the table are those gotten for the horizontal position, and those to the right of the line for the vertical. Column one represents the subject, column two the sex, column three the difference of vibration per second of the two A strings of the mandolin, column four the actual number of tests made upon the individual subject, column five the per cent. of right cases, column six the probable error, determined from the difference in vibration per second and the per cent. of right cases. The last column on the right of the table represents the per cent. which the probable error in the vertical position is of that in the horizontal.

This group of children was selected from a large grade, and represents those who have been in school the same number of years and who have had the same teachers. The children, therefore, represent a group having had precisely the same training so far as the school

is concerned, yet representing rather remarkable individual differences. The probable errors in the horizontal position vary from 1.3 to 10.6, though the latter is far above the mean. In the vertical posture they vary from 1.5 to 6, with a mean of 2.8.

It does not appear from the investigation that discrimination of pitch is very closely correlated with musical ability. Subject G is decidedly the most musical of the whole group, while subject M does not know the difference in tunes. A comparison of the probable errors shows that M's discrimination of pitch is more than twice as good as G's. The subject H. T., who does by far the poorest of the group in discrimination, has a beautiful voice and sings quite well, though she has difficulty in keeping on the key. She also plays the piano well for one of her age. Subject L, who has the best record for discrimination of pitch, is very bright in all lines, but takes no special interest in music, and does not sing at all. On the other hand, subject S, who has a very good record in discrimination, is musical. It does not appear, however, as a result of these tests that the two, musical ability and discrimination of pitch, are correlated.

It will be observed, too, by a comparison of the probable errors in the two positions of the body, that there seems to be, for this group, an advantage in the vertical posture, for the discrimination of pitch. The succeeding tables will show this same tendency even more markedly. There seems to be no physiological reason why sound waves should affect the organs of hearing differently in the two positions, and the fact is possibly to be explained on the basis of association and habit. Table IV shows that practice by those subjects who could discriminate much better in the horizontal posture, tends to reduce the differences of discrimination in the two positions of the body. This explanation should be further borne out by the fact that in adults, where habit and association are more deeply rooted, the differences in discrimination in the two positions are more decidedly marked. The mean comparative per cents. of the probable errors for the children is 93, and for the adults in Table II, it is 71. This seems too great a difference to be explained as a chance variation.

Explanation of Table II.—The method for obtaining the results in Table II was somewhat similar to that used for Table I. A balancing table was used for changing the subjects easily and quickly from one position to another, built somewhat on the plan of Mosso's instrument. The subject was placed upon this instrument in the horizontal position, and given ten tests, after which he was rotated to the vertical position and given more. This method was continued until one hundred tests in each position were made. Instead of the mandolin, the monochord was used for giving the stimuli. Middle C was the tone used as the standard, and the other string made to vary from this from one

TABLE II

This table is a summary of results of tests for discrimination of pitch upon twelve students in the University of Leipzig, by the use of the monochord.

		Horizontal				Vertical				
Subject	Sex	Δ	Number of experiments	Per cent right	P. E.	Δ	Number of experiments	Per cent right	P. E.	Comparative percents
G. L.	Male	3	100	83	2.12	3	100	92	1.44	66%
E. M.	"	2	100	70	2.56	2	100	74	2.1	82%
C. H.	"	4	100	85	2.59	4	100	81	3.0	117%
M. D.	"	2	100	92	.9	2	100	94	.85	94%
L. C.	"	2	100	60	5.26	2	100	82	1.4	27%
C. B.	"	3	100	68	4.34	3	100	74	3.15	73%
E. M.'	"	1	120	83	.7	1	120	89	.55	78%
C. W.	"	2	100	70	2.56	2	100	76	1.9	74%
M. A.	"	4	100	82	2.9	4	100	91	2.0	69%
G. S.	"	2	100	78	1.7	2	100	86	1.2	71%
M. S.	"	3	100	69	4.0	3	100	77	2.7	67%
L. C.	"	2	100	81	1.5	2	100	75	2.0	133%
				M. 76.7 M.V. 7.9	M. 2.5 M.V. .9			M. 82.6 M.V. 6.5	M. 1.8 M.V. .8	M. 71% M.V. 17%

to four vibrations per second, according to the threshold of the subject. The threshold was roughly determined in every case by a series of preliminary tests. As in the previous tests, the method of right and wrong cases was employed.

The important fact shown by this table is that out of the twelve subjects tested, ten do decidedly better in the vertical posture. The probable errors, which are correct measures of their discriminative ability, are a little over 1.4 times as large in the horizontal as in the vertical posture for the whole group. The individual differences are important in this group also. It will be seen that the probable errors in the horizontal position vary between the limits .7 and 5.26, when the mean is 2.5, and in the vertical position the extremes are 0.55 and 3.15 with a mean of 1.8. These differences are very striking indeed. The subjects were mostly students engaged in the study of psychology, and some of them had taken rather extensive laboratory courses.

Explanation of Table III.—The method employed in obtaining the results incorporated in this table was similar to those used in Tables I and II, save that the Koenig tuning forks were used for giving the stimuli. Two forks of 1024 vs. each were used, and by the use of a rider fastened upon one, the desired differences in vibration per second between the two forks could be secured. Great care was used in counting the beats for the desired difference. Several graduate students were

TABLE III

This table gives results of tests for discrimination of pitch upon nineteen students of Columbia University, by the use of Koenig tuning forks.

Horizontal						Vertical				
Subject	Sex	Δ	Number of experiments	Per cent right	P. E.	Δ	Number of experiments	Per cent right	P. E.	Comparative per cents
M.	Male	3	100	72	3.4	3	100	76	2.8	82%
C.	"	2	100	59	5.8	2	100	65	3.5	60%
G.	"	2	100	82	1.4	2	100	82	1.7	121%
D.	"	2	100	72	2.3	2	100	71	2.4	104%
J.	"	2	100	78	1.7	2	100	83	1.4	82%
S. G. T.	"	2	100	72	2.3	2	100	78	1.7	73%
L. C. S.	"	2	100	72	2.3	2	100	71	2.4	104%
J. G.	"	2	150	72	2.3	2	150	77	1.8	78%
E. L. M.	"	3	100	68	4.3	3	100	75	3.0	69%
F. M. H.	"	1	100	69	1.3	1	100	65	1.7	130%
S. F.	"	2	100	58	6.6	2	100	71	2.4	36%
F. L. W.	"	1	100	67	1.5	1	100	78	.88	58%
Prof. W.	"	1	100	68	1.4	1	100	75	1.00	71%
S. S.	"	1	100	59	2.9	1	100	64	1.8	62%
W. H. S.	"	2	100	72	2.3	2	100	84	1.3	56%
L. F. F.	"	2	100	58	6.6	2	100	66	3.2	48%
G. S.	"	2	100	79	1.6	2	100	88	1.1	68%
S.	Female	3	100	74	3.1	3	100	68	4.3	138%
B.	"	3	100	62	6.6	3	100	70	3.8	57%
				M. 69.1 M.V. 5.6	M. 3.6 M.V 1.9			M. 73.9 M.V. 5.6	M. 2.2 M.V. .8	M. 79% M.V. 21%

asked to count them independently, and then the average of the results was taken as the position for the rider to give the desired difference. For striking the forks, a felt mallet 20.5 cm. in length was used. It was found to be quite difficult to strike the forks evenly with this mallet, but after a considerable amount of practice it was possible to give practically the same amplitude to the vibration. Whatever slight deviations may have occurred were equally distributed in the two positions of the body and would tend to balance each other. The effort was constantly made also to strike the forks in precisely the same relative positions so as to produce the same quality of tone in every test. The forks were also sounded in a position relatively the same to the ear, whether the body was in the horizontal or vertical position. A Mosso's balance was provided by the Columbia Laboratory, upon which all the subjects in this series were tested, and the forks were placed on a small table five feet from the axle of the balance, and at the same height as the axle. This made the stimulus at an equal distance from, and in the same relative position to, the ear in both positions of the body. All the tests were made in the sound

room in the Columbia Laboratory, which is practically free from all disturbing stimuli.

In interpreting the results of this table, little need be said. There is a remarkable similarity to the results of the preceding table. There are only five subjects who could discriminate better in the horizontal than the vertical posture, and two of these, D. and L. C. S., do practically the same in both positions. All others show a very marked tendency to discriminate better in the vertical posture. For the whole group, discrimination is about 1.41 times as accurate in the vertical as the horizontal. Out of the nineteen subjects tested in this group five were selected for further practice, who had shown the greater difference in the two positions. It was thought that if the great difference found was due to association and habit, a definite amount of practice would tend to reduce the difference, and this was found to be the case. Table IV illustrates this point.

TABLE IV

Effect of practice upon five subjects chosen from those whose records are given in Table III.

Horizontal					Vertical				
Subject	Δ	Number of experi-ments	Per cent right after practice	P.E. after practice	Δ	Number of ex-peri-ments	Per cent right after practice	P.E. after practice	Com-para-tive per cents
F.L.W.	1	350	71	1.2	1	200	80	.8	67%
W.H.S.	2	350	74	2.1	2	200	83	1.4	67%
E.L.M.	3	400	72	3.5	3	250	77	2.7	77%
L.F.F.	2	300	61	4.8	2	200	65	3.5	73%
B.	3	300	63	6.1	3	300	69	4.0	65%
			M. 68.2 M.V. 4.9	M. 3.5 M.V. 1.5			M. 74.8 M.V. 6.2	M. 2.4 M.V. 1.1	M. 69% M.V. 4%

The practice effects shown in Table IV can best be summed up by a comparison of the last columns in the two tables. Subject L. F. F. increased his comparative per cent. from 48 to 73. Subject F. L. W. from 58 to 67. Subject W. H. S. from 56 to 67. Subject E. L. M. from 69 to 77. Subject B. from 57 to 65. It is evident that this increase in the comparative per cents. could be brought about either by improvement in the horizontal position, by doing worse in the vertical position, or by doing better in both positions, but improving more in the horizontal position than in the vertical. The latter seems to be the case. A comparison of the percentage of right cases of these subjects in the two tables reveals the fact that there is a little improve-

ment in the vertical position, but nothing to be compared with the improvement made in the horizontal. This, of course, would reduce the differences in the probable errors.

In this selected group, however, after the practice indicated in the table, there still remains a difference greater than shown in any other group tested. The mean probable error in the horizontal position is about 1.48 times as large as that in the vertical. It may be remarked that the writer believes the practice effects were carried to their limits in these subjects. The tests were carried on till there seemed to be no further improvement in either position, though this limit was reached more quickly in the vertical than in the horizontal position. Consequently, there seemed to be some conditions other than habit and association, which make subjects discriminate pitch better in the vertical than in the horizontal posture. This may be physiological, though, as has been stated, there is no good ground for supposing that sound waves would effect the organ of hearing any better in one position than in the other.

It only remains to sum up in one final table the total results of this investigation of the discrimination of pitch.

TABLE V

Average probable errors, percentage of right cases, and comparative percents taken from Tables I, II, and III.

Horizontal		Vertical		
Per cent right	P. E.	Per cent right	P E.	Comparative per cents.
M. 74.5 M.V. 4.4	M. 3.2 M.V. 1.4	M. 78.7 M.V. 6.5	M. 2.2 M.V. .8	83%

CHAPTER V

TACTILE DISCRIMINATION

Methods and Apparatus.—In the experiments described in this chapter, the effort was made to find whether there is a general tendency on the part of a group of subjects to have finer tactile discrimination *in one position of the body than in another.* The method here used was that of right and wrong cases, as in the discrimination of pitch. However, it was slightly modified in form to suit the use of the aesthesiometers. After a good deal of preliminary experimentation, it was found that practically all subjects can perceive a difference of 1 mm. with a large percentage of right cases, if touched upon the forehead with two aesthesiometers whose points are respectively 18 and 19 mm. That is to say, they can perceive in a large percentage of trials that the points in the two aesthesiometers are not the same distance apart, but will not be able to state whether the distance in the second is greater or less. This fact having been worked out experimentally, two aesthesiometers were made in the Columbia Laboratory, having

TABLE VI

Results of tests made on sixteen students of Columbia University in tactile discrimination, by the use of aesthesiometers.

Horizontal						Vertical				
Subject	Sex	Δ	Number of experiments	Per cent right	P.E.	Δ	Number of experiments	Per cent right	P.E.	Comparative per cents
M.	Male	1	100	85	.65	1	100	76	.95	146%
B.	"	1	100	70	1.28	1	100	60	2.63	205%
K.	"	1	100	75	1.00	1	100	75	1.00	100%
H.	"	1	100	68	1.45	1	100	72	1.16	80%
Mc.	"	1	100	72	1.16	1	100	65	1.75	150%
S.	"	1	150	88	.57	1	150	76	.95	166%
F.	Female	1	80	74	1.05	1	80	70	1.28	121%
F.′	Male	1	100	70	1.28	1	100	70	1.28	100%
L.	Female	1	100	79	.83	1	100	67	1.54	185%
F.″	Male	1	100	66	1.64	1	100	56	4.54	276%
C.	"	1	100	65	1.75	1	100	61	2.44	139%
J.	"	1	150	74	1.05	1	150	66	1.64	155%
S.′	Female	1	150	72	1.16	1	150	64	1.88	162%
D.	Male	1	100	68	1.45	1	100	78	.87	60%
M.′	"	1	100	74	1.05	1	100	66	1.64	156%
J.′	"	1	100	70	1.28	1	100	65	1.75	137%
				M. 73 M.V. 4.6	M. 1.16 M.V. .24			M. 68 M.V. 5.2	M. 1.7 M.V .59	M. 146% M.V. 36%

their points respectively 18 and 19 mm. apart. The method employed was to place the subject on the Mosso instrument in the horizontal position, and touch the forehead on opposite sides of the median line with the points of one of the aesthesiometers, and then after an interval of two seconds, to touch the forehead in approximately the same place with the other. The subject was then asked to state whether the points of the second were further apart or closer together than the first. By this means a table similar to the one for the discrimination of pitch was obtained. There was one difficulty in the method which seemed quite hard for subjects to overcome, and which may be worth mentioning; namely, some subjects claimed to be able to make a judgment of the distance of the points as soon as the first stimulus was given. It was proven by actual trial, however, in all the cases where this difficulty arose, that the subjects were not at all accurate in these judgments; nevertheless, they seemed to influence the results somewhat. However, whatever constant errors appear here from this cause, are equally distributed in the two positions, for the subject was rotated to the opposite position after every five tests. Fatigue entered very largely in these tests. For this reason only a few experiments could be made at one time, and a camel's hair brush was used to slightly sweep over the forehead after each experiment. This seemed to dispel the fatigue temporarily, and to stimulate the tactile organs. These tests were not hurried, but throughout them great deliberation was used. While only two seconds intervened between the two stimuli upon which judgment was to be rendered, plenty of time was taken between the two consecutive experiments to allow all the imagery of the previous test to disappear. When it was found that the subjects were confusing the actual sensation from the two points, with the previous images, the experimentation was concluded for that day.

Interpretation of Results.—It seems quite difficult to offer any satisfactory theory for the results found in this table. For this special group, the horizontal position is decidedly favorable for tactile discrimination. Only two of the subjects out of the sixteen can discriminate better in the vertical, while two others have precisely the same ability in the two positions. All of the others show remarkable preference for the horizontal, ranging in comparative per cents from 121 to 276. The means of the probable errors of this group have about the same relation to each other as those of the preceding tables on discrimination of pitch, but in an inverse ratio.

As was stated previously, a theoretical explanation of these results is somewhat dangerous, and must, of necessity, be rather arbitrary. The horizontal position seems favorable to the free flow of blood to all parts of the body. In this position, too, not having to overcome the

effects of gravity, the blood would naturally tend to flow away from the great splanchnic area, and in its general distribution, more of it would be supplied to the skin. It is even noticeable,[1] when subjects are rotated from the vertical to the horizontal position, that the face colors slightly, due to an extra flow of blood there. Howell[2] has shown that when a subject assumes the horizontal position and closes his eyes in the attempt to go to sleep, those portions of the arm within a plethysmograph undergo dilation. This dilation increases as sleep becomes more profound, showing that the skin and external organs were gorged with blood during sleep and horizontality. Whether this change in the circulation of the blood is the cause of sleep or the result of it, is difficult to say, but it seems to be quite plausible to suppose that, if in the horizontal posture there is an extra flow of blood to the skin, the tactile organs would be stimulated somewhat and would discriminate better. It may be said, on the other hand, that in this position the brain becomes anaemic, and there would be no reason to suppose that, even if the sense organs were more active, the central processes would be any more efficient. This argument might be answered in this way: sleep does ensue after a long time when the horizontal position is assumed, and all sensations are shut out as much as possible, and anaemia of the brain does accompany sleep in rather a definite ratio to its depth. But in the experiments under consideration, the subject was kept in the state of attention all the time, and there was no tendency to fall asleep. Besides the subject was not allowed to remain in the horizontal position long enough, according to the authorities, to cause the anaemic condition of the brain. On the other hand, the blood pressure changes almost immediately upon the change of posture, and the skin is thoroughly stimulated with fresh blood. If it is true, as has been shown in the chapter dealing with the literature of this subject by Vaschide and others, that an increased flow of blood to an organ increases its sensibility, then the results of this table seem to have a sound physiological basis. We would expect superior sense qualities in the skin, if by any means its blood supply is increased.

[1] Manaceine, *Sleep, Its Physiology, Pathology, Hygiene, and Psychology*, Chap. I.

[2] W. H. Howell, *Jour of Exp. Med.*, Vol. II, No. 3, 1897.

CHAPTER VI

A COMPARISON OF ADDING ABILITY IN THE HORIZONTAL AND VERTICAL POSITIONS OF THE BODY

The experimental study with which this chapter deals was an attempt to discover whether there is any marked tendency on the part of individuals to carry on such mental processes as are involved in addition, better in one position than in another. The method must, of course, be somewhat similar to that employed in the previous tests. Problems of equal difficulty were given for solution in the two positions of the body, and the results statistically compared. This was the method used in all three of the series represented by Tables VII, VIII, and IX, in this chapter.

The tests made upon the school children were not exactly under laboratory conditions, but the writer believes were sufficiently so to be valid. All the experiments were made in a quiet room, well lighted, and free from distracting stimuli. In place of the Mosso instrument, a cot was used for the horizontal posture, and the subjects were asked to stand up for the tests made in the vertical posture. In every case the subject's eyes were in the same relative position to the light in the two positions of the body, so that there was no chance for the figures on the card to be better lighted in one position than in another. The problems were theoretically of equal difficulty. Each problem contained the same digits an equal number of times, but in entirely different combinations. The following was one of the problems used for the children in their tests: 1, 3, 5, 4, 2, 6, 2, 3, 5, 1, 6, 4, 5, 2, 1, 6, 4, 3, 5, 4, 1, 6, 3, 2. These digits were arranged in a vertical column, to be added aloud in every case from bottom to top. It will be noticed that each of the six digits recur in this problem four times, and that with the same digits used the same number of times a great variety of combinations can be obtained, making the problems theoretically of equal difficulty. Of course, the answers to all the problems were the same. Subjects were told the character of the problems in the beginning of the experimentation, and that the answers were all the same. They were also told that all errors would be recorded in the adding process, and that therefore the mere obtaining of the correct answer was a small matter, if errors were made in the process. Subjects were then made to add aloud, beginning at the bottom of the column of figures, which were placed on a card three by eight inches. The sub-total for each digit was required to be given, thus allowing for only single combinations. On a duplicate card, which was held by the experimenter, all the sub-totals were arranged from the bottom

TABLE VII

Results of tests in addition made upon seven school children of the eighth grade in the public schools.

Subject	Horizontal posture													Vertical posture													Comparative per cents.
	Number of tests	Time		Errors										Number of tests	Time		Errors										
		M.	M.V.	1	2	3	4	5	6	7	8	9	10		M.	M.V.	1	2	3	4	5	6	7	8	9	10	
J. R.	18	26.8	4.2	3+	1+									18	25.2	3.9	5+ 1—	2+		1+							94%
M. A.	24	34.2	7.4	7+ 2—	4+	1+							1+	24	37.2	8.1	9+ 1—	4+ 1—		2+						1+	109%
L. G.	20	31.2	5.1	5+ 1—	2+	1+								20	33.4	6.0	8+	2+	1+								107%
G. D.	18	40.2	8.2	3+	5+	1—							1+	18	41.3	7.5	5+	2+	3+							1—	102%
S. C.	20	35.2	6.7	4+ 2—	1—									20	37.1	6.7	5+	3+	1—								106%
D. M.	15	30.7	5.2	6+ 1—	1+									15	31.3	6.4	5+	2+	1+								102%
D. F.	24	22.4	4.2	7+	1+									24	23.5	4.1	8+	2+ 1—								1+	105%
		M. 31.5 M.V. 4.3	M. 5.8 M.V. 1.3												M. 32.7 M.V. 5.2	M. 6.1 M.V. 1.2											M. 103% M.V. 4%

TABLE VIII

Results of tests made upon six students in the University of Leipzig.

	Horizontal posture													Vertical posture													
		Time		Errors											Time		Errors										
Subject	Number of tests	M.	M.V.	1	2	3	4	5	6	7	8	9	10	Number of tests	M.	M.V.	1	2	3	4	5	6	7	8	9	10	Comparative per cents
N.	20	42.4	5.8	8+ 2—	2+									20	46.3	5.7	7+ 1—	2+	1+	2+						1+	109%
S.	20	56.3	6.2	8+										20	57.1	8.2	7+	2+		1+						1+	101%
G.	24	27.2	3.2	5+										24	28.4	4.1	4+	1+								1—	105%
L.	18	30.4	4.8	9+ 3—	3+	1+								18	29.1	5.7	6+	3+	1+	1—						1+	95%
N.'	15	56.3	7.1	4+	4+	1+								15	56.8	8.2	4+ 2—	1+		1+						2+	100.8%
G.'	20	24.3	3.4	6+ 1—	2+	1—								20	25.3	4.1	7+ 2—	3+	1+	2+						1+	104%
		M. 39.4 M.V. 12.1	M. 6.0 M.V. 1.3												M. 40.5 M.V. 11.2	M. 6.0 M.V. 1.4											M. 102.4% M.V. 3.5%

TABLE IX

Results of tests in addition made upon fourteen students in Columbia University Laboratory.

	Horizontal position													Vertical position													
		Time		Errors											Time		Errors										
Subject	Number of experiments	M.	M.V.	1	2	3	4	5	6	7	8	9	10	Number of experiments	M.	M.V.	1	2	3	4	5	6	7	8	9	10	Comparative per cents
F.	24	22.5	2.4		1+									24	20.5	1.6											91%
M.	20	15.3	.7											20	16.4	1.5	4+										107%
C.	24	21.6	2.1	1+										24	23.5	2.6	2+										108%
P.	30	50.7	5.9		3+									30	56.4	4.1	2+	1+		1+							111%
W. H. S.	24	42.6	6.2	8+	2+								1+	24	44.4	7.2	3+	5+ 1—								1+ 1—	104%
D.	20	16.8	1.8	1+										20	16.5	2.3	2+										97%
F.	24	21.3	2.9	3+		1+								24	22.2	3.4	2+									1—	103%
Miss F.	12	25.3	3.1	3+	1+									12	27.0	4.1	3+	3+	1—								106%
W.	24	23.3	2.4	5+	2+									24	25.9	3.2	8+ 1—			1+						1+	112%
S.	20	21.5	4.3	2+	1+									20	21.5	3.9	3+ 1—	1+								1+	100%
Miss T.	12	38.7	4.1	4+ 1—										12	39.4	4.6	4+ 2—	1+									102%
H.	18	34.5	3.2	2+	1+									18	35.9	3.1	4+ 1—	2+									104%
Miss B.	20	19.7	1.9	2+	1+								1+	20	21.5	1.2	2+	1+									109%
Miss S.	18	15.3	1.8	2+									1+	18	14.3	2.4	1+	3+									93%
		M. 26.3 M.V. 8.7	M. 3.1 M.V. 1.2												M. 27.5 M.V. 9.4	M. 3.2 M.V. 1.1											M. 103% M.V. 4.8%

upward, so that all errors were easily detected. In this first series, the method of exposure was rather crude. The subject was asked to close his eyes, holding the card in his hand upon which was the problem to be added. At a given signal, he opened his eyes and added as fast as he could. A stop-watch recorded the time from which he named the first digit until the result was announced. A strict record of all errors, their number and size, and whether positive or negative, was kept, and they are shown in the accompanying tables.

An explanation of certain parts of Table VII is necessary. Under the column "time," will be found the mean for each subject to add the number of problems opposite his name, and also the variation from this mean. Under "Errors" are recorded the number and size of all errors, and whether they are positive or negative. For example, after M. A.'s name it will be observed that in the 24 problems which he added, he made 7 positive errors, and 2 negative of one point each. He also made 4 positive errors of two points each, and 1 positive error of three points. In addition to these, he made one positive error of ten points.

The result of this series of tests is readily seen from the mean times of adding all the problems in the two positions, and from the total errors in each position. The mean time for the horizontal position is 31.5 seconds, while it is 32.7 for the vertical position. There was a total of 61 errors made in the horizontal position, and a total of 78 made in the vertical. This shows a slight advantage for the horizontal position. As is to be expected, these differences are rather close; but it is believed by the writer that the test is sufficiently fine to bring out any real differences that are to be found in the adding process in the two positions of the body. Undoubtedly, the table does show a decided advantage for the horizontal position, which will be further shown in the two following tables.

The results of Table VIII do not seem to vary much from those found in Table VII. The mean time of adding all the problems in the horizontal position is 39.4 seconds, and for the vertical is 40.5. The number of errors is 60 in the horizontal, and 70 in the vertical. Here again is a decided advantage in favor of the horizontal position for the adding process.

It should be stated that with the above subjects the Mosso balance was used for rotating the subject from one position to another, and that the problems were harder, because of the fact that the digits 4, 5, 6, 7, 8, 9 were used in various combinations for forming the problems instead of 1, 2, 3, 4, 5, and 6. This accounts for the fact, which appears in the table, that the adults in the table added more slowly than the children represented in Table VII. The children probably would have added the latter series much more slowly, but the ratio

between the results of the two positions of the body as represented in the two tables is not very different.

All the tests, the results of which are found in Table IX, were made in the Columbia Laboratory, and the subjects were mostly psychological students, though some were used from other departments in the University. The tests were made in a dark room so that the quantity of light could be regulated in the two positions of the body. A sixteen candle power incandescent light was attached to the head of the Mosso instrument, which rotated with it, and thus furnished the subject with the same quantity of light in both positions. At a given signal this light was turned on, and the subject began to add as rapidly as he could. The stop-watch was started at the pronouncing of the first digit, and stopped when the result was announced. It was found, however, fully as satisfactory to have the subject close his eyes till the signal was given, and this method was largely used. In every case, the actual adding process was timed, and the averages taken for the total number of problems.

In this series of tests, only two subjects did better in the vertical posture, while the ratio between the means of all fourteen subjects in the two positions coincides very closely with the results of the previous tables. The horizontal mean time is 26.3 and the vertical is 27.5. The total number of errors in the horizontal position is 49, and in the vertical 71.

Some comment upon certain phenomena which manifested themselves during these adding tests seems necessary. Most of the subjects used were quite susceptible to fatigue in these tests, so it was deemed advisable when testing the Columbia students, to alternate the adding test with the tapping test, which will be explained in Chapter IX. By this means, the attention was not held directly upon the adding test longer than the adding of two problems, and then the subject was rotated to the opposite position and started off with the tapping test.

By this alternation, it is thought that very little adding fatigue appeared, and what did was equally distributed in the two positions of the body. In any particular subject, it was noticed that the speed of adding was materially lessened as experimentation went on. The practise effect from day to day on some of the subjects was quite marked, some improving in rapidity during the series as much as thirty per cent. A few did not improve at all, and some did worse at the close of the series. One feature in the experiments was quite noticeable with two of my subjects. They would apparently become confused toward the close of the column and make a sudden stop, having forgotten the sub-total and not being able to proceed. This did not seem to be due to fatigue, for their records after such experiences were as good or better than before. It appeared to be related to stage

fright, and was a temporary loss of memory. Another interesting fact appeared with reference to the relative time to solve problems when errors were made and when not. It was found that in the problems in which the greatest speed was attained no errors were made, but errors usually appear more frequently when the subject was adding slower than his usual rate. The table reveals another very remarkable thing in regard to the character of the errors. Out of a total of 389 errors, 355 are positive, and only 34 are negative. The writer cannot account for this tendency in nearly all adders to overestimate rather than to underestimate. That it is a rather universal tendency among all the subjects tested is shown clearly by a mere glance at either of the three tables. It will be noticed that the errors are mostly one point and two, with a good scattering of tens. However, the making of an error of ten in the adding process is really the equivalent of an error of one. It is merely a memory lapse in passing from one number in ten's order to another above. It must be said that any method of treatment of the valuation of errors in such tests is arbitrary, and in the present discussion entirely useless.

The method of adding aloud was very troublesome to some subjects, but was the only means of making complete records of all the errors. It should be said also that no subject was allowed to make combinations of numbers above the sub-total in mind and the number immediately above. Every sub-total had to be spoken aloud, so that in case an error had been made, it could be recorded.

Summing up the total results for the three tables previously given, we find that the mean time for all problems solved in the horizontal position is 30.6 seconds, and for the vertical position it is 31.7. The total number of errors in the horizontal is 170, and for the vertical 219. These figures measure accurately the subjects tested upon their ability to carry on the adding process in these two positions of the body, and indicate a marked preference for the horizontal position.

Any explanation of this fact will be pure theory. It seems, however, from the considerations in Chapter II on blood pressure, and cerebral circulation, that there is a somewhat more favorable opportunity in the horizontal posture for a free circulation of the blood through the brain, and consequently for the stimulation of the centers involved in the adding processes. This, together with the fact that all muscular tension is relaxed, the body is perfectly at rest, and the effects of gravity are not operating upon the blood vessels of the splanchnic area, thus allowing a freer distribution of blood to all parts of the body, seems to offer the only explanation possible. Certainly such a condition would not be favorable to muscular activity, as will be shown in another chapter, but there are some reasons why it should be considered favorable for the deeper mental processes.

CHAPTER VII

A COMPARISON OF PULSE RATE, BLOOD PRESSURE, AND VISUAL MEMORY IN THE HORIZONTAL AND VERTICAL POSITIONS OF THE BODY

The solution of two separate problems is undertaken in this chapter. First, a comparison of the three tests—blood pressure, heart-beat, and visual memory—is made for the two positions of the body, somewhat in the manner of the previous tests. Second, the effort is made to correlate the mental tests with physical conditions. The latter was determined by the method employed by Dr. Crampton, Assistant Superintendent of Physical Training in the New York City schools, and consists in a grading of the subjects as A, B, C, D, E, F, G, H, and I, according to the relative blood pressure and heart-beat in the two positions of the body. Thus as he states:

"The total change of blood pressure in those who may be considered in health is from plus 10 mm. to minus 10 mm. Hg. That of pulse rate is from plus 5 to plus 35." Dr. Crampton then states that it is possible to divide the whole range of individuals into fifths, and he constructs a tentative table in which the letters constitute the index to the splanchnic efficiency as follows:

Blood pressure increase		+10	+5	0	—5	—10
Increase in heart rate	5	A	B	C	D	E
	12	B	C	D	E	F
	20	C	D	E	F	G
	28	D	E	F	G	H
	35	E	F	G	H	I

The above grades then constitute a sort of index to the splanchnic efficiency of the individual, and it is believed give a valid gradation of individuals with reference to their physical condition.

At any rate I have accepted the results obtained by Dr. Crampton as valid, and have performed the tests for blood pressure and heart-beat according to his directions. All my subjects who were tested for visual memory were at the same time tested as to heart-beat and blood pressure, the experiments alternating in the following order: First, heart-beat; second, blood pressure; and third, visual memory.

The method of taking this extended series of tests should be explained in detail. All of the tests were made in one of the sound rooms in the Columbia University Laboratory, which is also a dark room. Here it was possible to regulate the light, as in the previous tests, by attaching an incandescent lamp of sixteen candle power, directly to the head of the Mosso instrument, and in a favorable position to shade the eyes and yet shine directly upon the card-holder placed in the proper position in front of the eyes. The cards upon which were the

digits to be visually remembered were equally illuminated, and in the same relative position to the eyes in both positions of the body. The order in which the experiments were made was as follows: The subject was first placed on the balance in the horizontal position, and after having remained there for about two minutes, so that the circulatory organs were completely adjusted to this position, the pulse was counted, the full number per minute. The systolic blood pressure was then taken; the instrument used for this purpose was the Riva-Rocci sphygmomanometer. Care was taken to take these measurements in the manner prescribed by Dr. Crampton in his tests upon the school athletes of the New York City schools. It is thus possible to grade the subjects physically as he did, and to compare their physical condition with mental ability. After these two physical tests were made and recorded, the visual memory test followed. For this experiment, cards two and a half inches by seven inches were prepared, upon which eleven digits were placed in rather large figures, lengthwise of the card. The following is an example of one of the series of digits to be learned visually: 7, 1, 3, 5, 9, 6, 2, 8, 4, 1, 3. The card was then placed in the card-holder directly in the field of vision of the subject, and at a given signal was exposed to view for four seconds. He was asked to learn them visually from left to right, if not all, as many as he could in the four seconds. Subjects were cautioned not to use lips, tongue, palate, or even muscular imagery of the digits to be learned, and at end of four seconds the exposure ceased, and he was asked immediately to repeat the digits in the order learned from right to left. A record was kept of those digits correctly given. After a few seconds, the card was exposed a second time and the subject asked to renew his efforts to learn the series. This was continued until the digits were correctly given. By this means it was possible to keep an accurate record of all errors made by each subject, as well as the number of trials to learn the series. Both of these facts are taken into consideration in determining the mental efficiency in visual memory on any subject. Then, before the subject was elevated to the vertical position, the heart-beat and blood pressure were again taken, so that by the greater number of tests, an average would be reached which would include all variations due to change in physical condition or any other causes.

In Table X are embodied the results of the long series of tests previously described. In visual memory, it includes 630 tests made upon 27 subjects, and for blood pressure and pulse beat, the number of tests is doubled, for the reason that these both preceded and succeeded each visual memory test. In order that the table may be perfectly clear, some explanation may be necessary. Take, for example, subject "H," the first one in the list. Under the column, "pulse rate,"

TABLE X

Comparative results of pulse rate, blood pressure, and visual memory in the horizontal and vertical positions of the body.

	Horizontal							Vertical								
	Pulse rate		Blood pressure		Visual memory			Pulse rate		Blood pressure		Visual memory				
Subjects	M.	M.V.	M.	M. V.	Number of tests	Mean trials	Errors	M.	M.V.	M.	M.V.	Number of tests	Mean trials	Errors	Physical rank	Memory rank
H.	65.0	3.0	112.2	2.4	10	5.3	340	79.5	1.2	127.2	2.3	10	4.0	125	B.	C.
B.	94.2	4.3	109.1	3.7	12	3.2	120	101.4	3.7	117.3	5.3	12	7.4	263	A.	D.
S.	81.5	2.6	120.2	4.6	10	2.6	94	87.5	2.1	130.5	4.6	10	3.7	152	B.	B.
S.′	62.2	4.1	112.3	3.6	10	3.5	122	80.1	3.2	118.1	3.5	10	5.3	235	D.	B.
M.	57.0	2.3	124.5	1.2	12	3.2	53	69.1	2.3	132.2	6.1	12	4.1	117	B.	B.
R.	65.6	8.9	122.6	4.1	12	4.2	137	78.2	3.5	133.6	2.5	12	5.2	206	B.	C
C.	66.0	2.4	112.6	3.1	15	6.3	205	97.2	2.3	112.2	2.6	15	4.1	213	F.	D.
S.″	63.7	1.5	120.0	2.8	10	7.4	146	72.3	4.6	130.2	3.6	10	6.3	162	A.	E.
F.	68.2	2.4	126.3	3.4	12	8.3	265	89.4	3.2	119.0	1.4	12	9.4	272	G.	G.
F.′	83.0	1.5	138.2	4.6	12	4.3	275	95.2	3.6	142.0	2.6	12	5.7	292	D.	D.
G.	64.1	3.7	115.6	2.3	12	7.4	362	69.1	4.2	112.6	4.8	12	7.9	387	D.	F.
L.	60.5	4.1	126.5	4.9	10	4.2	253	64.2	2.1	118.2	3.5	10	4.1	271	D.	C.
A.	82.3	4.5	118.2	2.7	10	3.6	187	91.2	3.6	126.3	2.3	10	4.1	162	C	B.
C.′	74.1	2.1	126.3	4.6	14	4.7	162	85.3	1.4	135.2	3.5	14	5.2	208	B.	C.
D.	60.2	2.1	112.3	2.4	9	5.7	153	76.2	1.5	122.2	2.6	9	5.2	236	C.	D.
J.	80.2	3.1	120.3	1.5	12	6.3	246	85.2	3.9	118.2	1.4	12	7.4	311	D.	E.
S.‴	70.5	4.8	112.3	4.6	10	2.3	111	85.7	3.2	122.4	4.5	10	3.5	214	B.	B.
N.	59.1	2.6	124.2	3.2	10	8.6	189	60.2	2.4	110.2	3.1	10	9.4	265	F.	H.
H.′	68.2	1.4	126.2	4.1	18	5.1	226	75.7	2.3	118.4	2.6	18	7.9	246	D.	E.
D.	70.5	3.1	113.5	2.6	11	9.2	364	69.3	5.2	109.2	3.5	11	9.4	372	E.	H.
M.′	82.3	4.2	115.6	3.5	10	4.5	172	94.2	4.6	122.3	4.1	10	3.1	268	C.	B.
K.	90.4	3.2	108.2	4.3	12	7.6	267	92.3	3.5	100.6	3.6	12	8.9	341	E.	G.
A.′	82.1	5.2	112.6	4.7	10	4.3	152	91.1	4.1	120.2	4.6	10	5.1	164	C.	C.
L.	71.2	3.1	118.6	3.9	18	6.5	190	82.2	2.3	128.5	2.7	18	4.3	140	B.	D.
I.	64.2	2.1	112.6	2.5	10	5.1	162	71.5	3.1	120.2	3.1	10	6.7	208	C.	D.
S.⁗	80.1	4.5	118.6	4.7	14	4.2	278	85.6	5.2	127.6	4.2	14	5.3	367	A.	C.
P.	65.1	2.8	110.6	3.8	10	3.1	152	71.2	3.1	116.2	2.3	10	5.1	165	B.	C.
	M. 71.5 M.V. 8.5	M. 3.3 M.V. 1.2	M. 118.1 M.V. 5.7	M. 3.5 M.V. .9		M. 5.2 M.V. 1.5	M. 199 M.V. 66	M. 81.5 M.V. 9.1	M. 3.2 M.V. .8	M. 121.8 M.V. 7.1	M. 3.4 M.V. .9		M. 5.8 M.V. 1.3	M. 236 M.V. 58	$r=$	70.7

the mean for twenty tests in the horizontal position was 65, with a variation of 3. Under the column, "blood pressure," the mean for twenty tests in the horizontal position was 112.2, and the mean variation 2.4. Under "visual memory," by the use of ten separate cards, the mean number of trials to learn the series of eleven digits on each card was 5.3, making a total of 340 errors. In the vertical position, similar columns will be observed, having the same significance as those in the horizontal position. We are only concerned in a comparison of the results in the two positions.

It will be conceded, I think, that the visual memory tests, taking into consideration their number for each individual subject, and that every error was recorded, and that the table indicates the average number of trials to learn the series visually, furnish a reliable test of the ability of the subjects in visual memory. Either the total number of errors or the mean trials for each subject make a sufficiently fine test to enable us to determine with precision the relative ability of these subjects. As will be seen later, upon the basis of these results, it is possible to divide the subjects into groups, somewhat after the fashion that Dr. Crampton divided his subjects for physical condition. The actual method of doing this was to arrange the records for visual memory, found in Table X, in a series beginning with the lowest and ending with the highest. By dividing the difference between the highest and the lowest of these records into nine equal parts we secure a gradation of subjects for visual memory which corresponds to the gradation by Dr. Crampton for physical condition, as A, B, C, D, E, F, G, H, and I. When this is done it is then only necessary to divide them into groups as to physical condition in precisely the same number that he did, in order to correlate the two groups and see how far one is coincident with the other. While this correlation of mental and physical tests is not directly involved in my problem, it is an interesting side light upon a problem which has been attacked by several writers and may suggest a fruitful method for further research. The usual method which has been employed has been to compare the grades obtained by college or university students in their academic work with the grades or standing in the department of physical training. One serious objection to the validity of such comparison is that the grades thus compared are upon as many different standards as there are different departments and professors. It has been proven[1] that there is very little validity in grades of any sort unless a probable error is assigned, and this would be much more so when a large number of grades are compared which have not been standardized. The method herein employed has the advantage of correlating mental and physical tests taken at the same time and under the same extremely

[1] Cattell, "Examinations, Grades and Credits," *Pop. Sci. Mon.*, Feb., 1905.

careful laboratory conditions. All tests were made by the same experimenter, and the individuals are arranged serially into groups in precisely the same manner for the mental as for the physical tests. Thus as nearly as possible, the two groups are standardized, being arranged in both series according to the probability curve, which is valid for most mental and physical characteristics.

TABLE XI

Correlation of visual memory with physical condition, by method of unlike signs.

A = 1; B = 2; C = 3; D = 4; E = 5; F = 6; G = 7; H = 8.

Rank	Visual memory	Rank	Physical condition
B	2—	B	2—
B	2—	B	2—
B	2—	D	4+
B	2—	B	2—
B	2—	C	3—
B	2—	C	3—
C	3—	B	2—
C	3—	B	2—
C	3—	D	4+
C	3—	B	2—
C	3—	A	1—
C	3—	C	3—
C	3— Median=3.87	B	2— Median=3.39
D	4+	D	4+
D	4+	F	6+
D	4+	A	1—
D	4+	C	3—
D	4+	B	2—
D	4+	C	3—
E	5+	D	4+
E	5+	D	4+
E	5+	A	1—
F	6+	D	4+
G	7+	E	5+
G	7+	G	7+
H	8+	F	6+
H	8+	E	5+

In Table XI the two columns, "physical rank" and "memory rank," should be noted. After arranging the twenty-seven subjects tested into eight groups, distinctly marked from each other by the results of the tests for physical condition and visual memory, it was desired to find how far the individuals found in the several groups for physical condition were also found in the corresponding groups for visual memory. In other words, the problem was to determine the correlation between the physical rank and visual memory of the twenty-seven subjects tested in the two series. The method employed was that known as the "method of unlike signs." By reference to Table XI it will be observed that six of the subjects tested in visual memory are ranked as "B," seven are ranked as "C," six as "D," three as "E," one as "F," two as "G," and two as "H." The median of this

series of numbers is found to be 3.87. In the column just opposite that of visual memory is found the rank of the corresponding individuals for physical condition. The median of this series of numbers is 3.39. The signs are affixed to each rank in both columns, negative when below the median, and positive when above. Comparing the signs in the two series, seven are unlike or 25.9 per cent. of the whole have unlike signs. Substituting in the formula $r = \cos \pi U$, in which r is the coefficient of correlation, and U the per cent of unlike signs,[1] we get $r = 70.7$ per cent.

From Table X the results of this extended series of tests are easily summed up. It will be observed that the mean for the heart-beat of all subjects tested is 71.5 for the horizontal position, and 81.5 for the vertical posture. Only one subject in this group, namely, "D," has a higher rate of pulse in the horizontal than in the vertical position. Thus the whole series of tests as well as those of the succeeding chapter show clearly that there is a tendency to an increase of heart-beat when the body is elevated from the horizontal to the vertical posture. The same general tendency holds also for blood pressure, though here we find one-third of the subjects having a higher pressure in the horizontal than in the vertical position. This is an indication, as has already been shown in Chapter II, that in these subjects the vaso-motor mechanism is not adequate to the physical adaptation necessary to counteract the effect of gravity in the vertical posture. According to Dr. Crampton, these subjects must be regarded as in bad physical condition. From the percentage of correlation already found, it is seen that they are also in poor mental condition; at least they are not efficient in the mental tests herein recorded. The mean blood pressure of all subjects tested for the horizontal posture is 118.1, and for the vertical it is 121.8. It must be said that this slight difference in the two positions is due to the large number of those who may be said to be abnormal in the vaso-motor mechanism.

In regard to the memory tests, my subjects do decidedly better in the horizontal position. Only six out of twenty-seven do better in the vertical position, and four of these do practically the same in the two positions. The mean trials to learn the series in the horizontal posture for all subjects of this series is 5.2 and in the vertical it is 5.8. The mean errors made in the horizontal posture is 199 and in the vertical it is 236. Taking into consideration these two sets of averages, there is no doubt that for these subjects the horizontal position is preferable for visual memory.

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[1] For a table giving the values of r corresponding to each value of U, the writer is indebted to Professor Thorndike.

CHAPTER VIII

A COMPARISON OF PULSE RATE, BLOOD PRESSURE, AND AUDITORY MEMORY IN THE HORIZONTAL AND VERTICAL POSITIONS OF THE BODY

Immediately upon the completion of the extended series of tests recorded in the previous chapter, the writer began a similar series on auditory memory. These experiments were made in the Columbia Laboratory, and under the same conditions as the preceding. All were made in one of the sound rooms, which is also a dark room. The conditions for testing auditory memory were thus most favorable, all other stimuli being eliminated as nearly as possible. As in the preceding chapter, the effort is made to find the correlation between physical condition and auditory memory. The pulse rate and blood pressure are taken both before and after each auditory memory test, in both positions of the body, so as to insure large enough an average to eliminate any physiological variations that might occur. The method is thus seen to be practically the same as in the preceding chapter, though a word needs to be said concerning the method of taking the auditory tests.

The subject was placed upon the Mosso instrument in the horizontal position, and after the heart-beat and blood pressure were taken, a series of eleven digits were read slowly to the subject. As soon as the reading had finished, he was asked to repeat the series aloud, beginning at the first and proceeding as far as he could. The experimenter was supplied with a sheet of paper, having written at the top the series read, and as the subject repeated the digits all errors were carefully recorded. This was not a difficult matter, for when an error was made, having the series directly above, the experimenter could quickly check off the digit wrongly repeated. Eleven digits were chosen as about the right length of series, because it was thought that no subject could learn them auditorily in one reading. This was found to be the case, though the subject S.‴ did learn one or two of the series in one reading. No other subject was able to learn them in less than three readings. Taking into consideration the number of times for each subject to learn the series, and the number of errors made, the test becomes extremely fine, and leaves no doubt as to the validity of the results in determining the auditory memory powers of the subjects tested.

It should be remarked that all subjects were cautioned against learning the series in any other manner than auditorily. They were asked to inhibit all lip movements, movements of the larynx or tongue, and were asked to refrain from any visualizing of the digits after hearing

them, so as to aid the memory. Of course, it must be conceded that this is totally impossible with some subjects, and it is entirely probable that no one remembers in a purely auditory manner. The auditory impression is, for most individuals, mixed with visual imagery, as well as muscular and tactual. Still the writer believes that the test is valid for auditory memory, so-called.

It should also be remarked that the fifteen subjects used in this series were trained subjects, having had the experience of the preceding tests. Thus we have here a very convenient means of making comparison of visual with auditory memory. While this is not directly bearing upon my problem, it is worth while to call attention to the individual differences which these fifteen subjects exhibit. For example, Subject "B" learns the eleven digits visually, in the horizontal position, in 3.2 mean trials, while in the same position, it takes him 7.9 mean trials to learn the similar series auditorily. In like manner subjects "L," "K," "A," and "N" exhibit rather remarkable individual differences.

In both series of memory tests, four different classes of errors appeared. First, the substitution of one digit for another; second, the omission of a digit; third, a digit inserted; fourth, digits placed in their reversed order. Any method of valuation of errors yet devised seems quite arbitrary; therefore, in estimating the number of errors in any series of experiments as recorded in either Table X or Table XII, the writer makes no discrimination as to the character of the error. In other words, each error made, of whatever character, counts one. The number in the table thus shows the total number of errors in learning the different series.

It may be said that the results of the tests in auditory memory, as shown in Table XII, are the reverse of what was expected, after having found that the vertical position is slightly favorable to discrimination of pitch. However, Table XII shows that the horizontal position is favorable for auditory memory, as it is also for visual memory. The average number of errors per individual in the horizontal position is 227, with a M.V. of 64. In the vertical position, the average number of errors per individual is 250, with a M.V. of 64. The average number of trials given each individual to learn the series in the horizontal position is 6.3. with a M.V. of 1.3, while in the vertical position each individual has on an average 7.3 trials to learn the series, with a M.V. of 1.4. It, therefore, seems evident both from the standpoint of the number of errors made by each subject, and from the rapidity with which the associations are remembered, that the horizontal posture is favorable to auditory memory, with the subjects tested in this series.

The validity of the blood pressure and heart-beat records is amply shown by a comparison of Tables X and XII. It will be noticed that

TABLE XII

Comparative results of pulse rate, blood pressure, and auditory memory in the horizontal and vertical positions of the body.

	Horizontal							Vertical						
	Pulse rate		Blood pressure		Auditory memory			Pulse rate		Blood pressure		Auditory memory		
Subject	M.	M.V.	M.	M.V.	Number of tests	Mean trials	Errors	M.	M.V.	M.	M.V.	Number of tests	Mean trials	Errors
B.	93.8	4.5	110.2	3.9	14	7.9	235	103.2	3.6	116.8	6.2	14	8.4	262
S.'	63.2	4.6	109.0	4.1	10	5.7	178	82.3	4.1	120.2	4.3	10	5.8	175
R.	65.4	9.2	118.5	3.7	18	5.6	111	79.3	3.6	130.5	2.9	18	7.8	190
C.	67.8	3.7	113.5	3.7	12	4.1	242	95.6	2.7	110.6	3.1	12	6.4	301
F.'	85.1	2.1	136.4	4.6	12	6.8	156	94.8	3.9	140.1	3.4	12	7.1	183
L.	62.1	4.3	122.0	5.3	10	8.2	261	68.3	3.5	120.4	4.2	10	9.4	283
A.	84.6	5.1	116.8	3.5	18	5.2	145	92.0	3.9	123.5	2.7	18	7.2	162
D.	63.1	3.5	113.1	3.5	12	7.7	179	77.2	2.3	122.1	3.5	12	7.9	195
S.'''	71.2	5.2	109.6	5.2	10	3.5	118	86.2	3.8	118.6	5.1	10	5.2	165
N.	62.3	3.8	120.3	5.2	12	7.4	269	64.2	3.8	114.1	5.2	12	8.9	314
H.'	69.1	2.3	124.0	4.6	16	4.2	274	75.8	3.4	120.2	4.1	16	5.3	312
M.'	83.4	4.6	116.8	3.8	18	7.2	414	94.8	4.7	123.5	4.6	18	9.1	383
K.	92.1	4.1	109.2	4.6	10	9.1	321	92.6	4.6	104.2	3.6	10	10.3	362
C.	72.0	4.2	119.5	4.6	12	6.4	279	83.4	5.1	119.2	5.1	12	7.2	200
G.	65.2	3.1	111.3	4.5	12	5.6	224	72.2	4.1	117.5	3.3	12	4.1	265
	M.	M.	M.	M.		M.	M.	M.	M.	M.	M.		M.	M.
	73.4	4.3	116.7	4.3		6.3	227	84.1	3.8	120.1	4.0		7.3	250
	M.V.	M.V.	M.V.	M.V.		M.V.	M.V.	M.V.	M.V.	M.V.	M.V.		M.V.	M.V.
	9.6	1.0	5.4	.5		1.3	64	9.4	.5	5.3	.8		1.4	64

in the extended series of experiments each subject tested shows very little variation. This is due to the fact that such a large number of records were taken for each individual, and the mean actually shows these two physiological phenomena for each individual tested. It is impossible to determine normal heart-beat or blood pressure of an individual by a few tests, because slight external influences, which the experimenter may not be able to control, are sure to make considerable variations in both, making it necessary to obtain a large number of results from tests under varying conditions.

By arranging these fifteen subjects into two series, one for physical condition, and the other for efficiency in auditory memory, the correlation was found by the same method as in the preceding chapter, with r equal to 68.2. This result makes it quite certain that for the subjects tested in visual and auditory memory, there is a decided correlation between their mental efficiency in these two lines and their physical condition, based upon a comparison of heart-beat and blood pressure in the two positions of the body.

CHAPTER IX

A COMPARISON OF TAPPING RAPIDITY IN THE HORIZONTAL AND VERTICAL POSITIONS OF THE BODY

It was said in the preceding chapter that the adding tests were alternated with the tapping tests. This was done in connection with the experiments conducted in the Columbia Laboratory only. It was thought by this method that fatigue for both sets of tests was somewhat avoided. The tapping tests were conducted in the following manner: A small brass pencil was held in the fingers in a convenient position for tapping upon another piece of sheet brass which was clamped to the Mosso instrument, in such a position that when the arm was straightened out along the balance, the tapper came directly over the piece of sheet brass. A record of the taps was kept by an electric tabulator, made by Stoelting, of Chicago, and the subject was timed with a stop-watch for one hundred taps. Of course, when the subject was rotated from one position to another, the hand remained in the same relative position to the balance and to the piece of sheet brass upon which the taps were made. There is, of necessity, a slight difference in the physical conditions, for in the horizontal position the weight of the hand has to be lifted in making every tap, while in the vertical posture the hand has only to make a swinging movement similar to that of a pendulum. We would naturally expect this to make some difference in the rapidity with which the movements could be made.

Reference to Table XIII will show the comparative rapidity of this reaction in the two positions of the body. All but two of the subjects tested did better in the vertical posture, and one of these, Miss F., does practically the same in the two positions, but has a greater M.V. in the horizontal. However, taking into consideration the regularity of her speed in the vertical position, she really did better in the latter. A comparison of the means in the two positions for all subjects tested shows that the vertical posture is slightly favorable, there being an advantage of about four taps per hundred for this position.

It is worthy of note in connection with this series of tests that the subjects showed great individual differences in the manner of innervating the necessary muscles for producing the movement. They were asked to keep the body perfectly still while making the tapping movement and cautioned against the use of more muscles in the execution than absolutely necessary. Nevertheless, in at least eight of the subjects, there were marked movements in other parts of the body, particularly in the opposite arm and leg, and even in the muscles

TABLE XIII

Comparison of taps made in the horizontal and vertical positions of the body. Number recorded by an electric tabulator.

Horizontal				Vertical			
Subject	Number of tests	Time		Number of tests	Time		Comparative per cents
		Mean	M.V.		Mean	M.V.	
F.	24	12.4	.5	24	12.4	.7	100%
M.	20	12.7	.4	20	12.3	.6	97%
P.	30	13.05	.8	30	12.1	1.2	93%
W.H.S.	24	11.7	.9	24	11.0	.8	94%
D.	20	11.9	1.4	20	11.7	.3	98%
F.	24	14.3	1.2	24	13.1	.9	91%
Miss F.	12	16.6	2.1	12	16.7	1.4	100.6%
W	24	17.0	1.8	24	15.2	.7	89%
S.	20	13.5	.9	20	12.7	.8	94%
C.	24	15.05	.17	24	14.4	.4	95%
Miss T.	12	18.4	.5	12	17.9	.6	97%
H.	18	12.9	.4	18	12.2	.5	94%
Miss B.	20	14.8	.2	20	14.4	.6	97%
Miss S.	18	14.2	.2	18	14.4	.3	101%
		M. 14.2 M.V. 1.5	M. .8 M.V. .5		M. 13.6 M.V. 1.59	M. .7 M.V. .2	M. 95.7% M.V. 3.2%

of the shoulder and neck, to such an extent that the head moved rapidly from side to side. Even if the movements did not show themselves in other parts of the body, it was evident that practically all the leading muscles of the skeletal system were violently contracted. Most of the subjects stated that this state of muscular contraction aided them very materially in the rapidity of the movements. It is to be noted, however, that the three subjects making the best records in the whole series did not show this violent muscular tonicity in other parts of the body, neither did there appear much irregularity in the breathing or other bodily functions. Those making the best records seemed to have the power to inhibit all impulses to other muscles save those needed for these rapid movements. The subject W. H. S. who ranks first in the series, and who twice during the tests made one hundred taps in nine seconds, equaling the world's record, so far as the writer has been able to discover, made the movements with apparent ease and without any muscular changes or innervations in other parts of the body. These tests would thus seem to show that as in accuracy of movement, so in rapidity of movement, the best results are attained by inhibiting all impulses to the musculature except those absolutely necessary to the movement itself. If this theory be true, we would expect to find much improvement by practice, which does actually appear from the tests made in this series. With-

out exception every subject made considerable improvement during the extensive series taken, and those improved most whose innervation to other muscles was greatest in the beginning. Of course their attention was constantly called to the unnecessary movements they made, and gradually they tended to disappear and greater speed was acquired. Rapid movements thus appeared to conform to the law of all highly specialized movements. The athlete who wins is he who knows the form of the movement to be made and is able to inhibit all unnecessary movements. The nervous energy set free in the peripheral centers thus passes directly into the motor centers concerned in the sending on of the impulse to the proper muscles, and there is no waste. The nervous energy[1] being confined within narrower limits has greater facility in passing the synapses, thus making the movement more quickly. The secret of being able to make rapid movements is thus the ability to control the nervous energy set free in the sensory centers into the precise motor centers needed to make the movement.

There are some reactions, such as holding the breath and violent facial contortions, which were very noticeable in some of the subjects who did poorest in these tests. One subject portrayed such violent muscular contractions, and inhibited breathing to such an extent during the whole experiment that after each test he seemed almost exhausted, and a considerable space of time had to be taken for recuperation, before the accompanying tests already mentioned could be continued. Such subjects always do poorly in these tests. No such widely distributed muscular effort was evident in the subjects who made good records. On the contrary, the vibratory movements of the greatest rapidity were always very short, and unaccompanied by any motor effects in any other part of the body.

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[1] McDougall, *Physiological Psychology*, p. 32.

CHAPTER X

A COMPARISON OF FATIGUE IN THE HORIZONTAL AND VERTICAL POSITIONS OF THE BODY, BY THE USE OF THE FINGER DYNAMOMETER

The method of taking this rather tedious series of tests was similar in character to all of the previous series, that is, the subject was placed upon the Mosso instrument in the horizontal position, and made to press the finger dynamometer (the Cattell instrument) fifty times, from the record of which, the fatigue curve could be calculated. Then after sufficient time had elapsed to allow the fatigue to pass away, the test was repeated in the vertical posture. For the greater number of the subjects, only one test could be taken per day, though some were able to take one in the forenoon, and one in the afternoon, allowing as much as three or four hours to intervene. In every case, there was positive assurance that the effects of the previous test had passed away before the next was taken. In some cases several days elapsed between the tests in the two positions.

In making the tests, the instrument was held in precisely the same relative position to the body, whether in the horizontal or vertical posture. The arm and wrist were made to rest upon the Mosso instrument at the side of the body, in a convenient position for operating the instrument, which was held between the thumb and forefinger of the right hand. At a given signal, the subject was asked to press the dynamometer as hard as he could, once per second for fifty seconds. Subjects were cautioned to inhibit all other movements as much as possible, and to exert themselves in doing their best at each successive effort.

In estimating the relative ability of subjects to press the dynamometer, the method adopted by Wissler[1] has been used throughout. Each subject was tested at least ten times in each position, and the figure in the "fatigue" column represents the mean for all these tests. Of course, the fatigue will be shown by the degree of approximation to the initial effort. It is very true that some subjects do not know when they have done their best, and the initial effort is not so good as some of the later ones. Then it may be that some subjects cannot do their best until they are "warmed up." However, the writer believes that in the extended series, the results of which are given in Table XIV, the inadequacy of the initial efforts makes no difference in the validity of the comparative results herein tabulated. The effort is only to determine differences, if any occur, in the horizontal and vertical

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[1] Wissler, *The Correlation of Mental and Physical Tests*, p. 38.

TABLE XIV

A comparison of fatigue by the use of the finger dynamometer in the horizontal and vertical positions of the body.

Horizontal				Vertical			
Subject	Number of tests	Fatigue	M.V.	Number of tests	Fatigue	M.V.	Comparative per cents
L.	10	70.3	5.8	10	73.5	6.1	104%
G.	12	85.2	7.4	12	86.8	5.3	102%
T.	10	91.4	8.4	10	90.2	8.7	98%
M.	12	72.1	5.7	12	78.6	6.4	109%
M.′	15	65.4	3.8	15	69.5	4.7	106%
A.	12	81.1	7.1	12	88.3	8.4	109%
S.	10	85.2	6.3	10	90.2	5.4	106%
W.	10	74.8	4.7	10	80.6	5.3	108%
T′	12	81.7	3.2	12	84.6	4.6	103%
G′	10	74.3	5.6	10	78.2	6.1	105%
L′	10	85.5	7.2	10	90.3	6.8	106%
A′	12	64.4	5.2	12	70.6	3.8	108%
B.	10	87.7	4.9	10	90.6	5.6	103%
D.	10	84.1	3.9	10	88.6	2.9	105%
		M. 78.8 M.V. 7.3	M. 5.5 M.V. 1.2		M. 82.8 M.V. 6.6	M. 5.7 M.V. 1.1	M. 105% M.V. 2.2%

position of the body. For example, subject "L" has a fatigue record in the horizontal position of 70.3, and in the vertical of 73.5. These figures are obtained as follows: For each test made, the total reading was divided by five times the sum of the first ten pressures. These results were added together and divided by the total number of tests made, as indicated in column two of the table.

The results of the tests are quite conclusive so far as the subjects tested are concerned. Much greater fatigue is shown in the horizontal posture than in the vertical. The mean for the horizontal is 78.8, and for the vertical is 82.8. The comparative per cents. show that the quantity of fatigue shown in the horizontal position is approximately 105 per cent. of that shown in the vertical position.

Theoretically, this would be expected. The vertical posture is normal for muscular effort. When the weight is thrown upon the feet and the blood pressure is increased throughout the body, the tonicity of the whole musculature is more easily sustained, and muscular co-ordination facilitated. Mere force of habit and association would aid the muscular effort in the vertical posture, for one rarely engages in any violent exercise in the horizontal posture. The latter posture is used for repose habitually, and is not surprising that muscles are more readily fatigued under great activity when in a position in which they are normally relaxed.

CHAPTER XI

A COMPARISON OF THE STRENGTH OF GRIP, BY THE USE OF THE HAND DYNAMOMETER, IN THE HORIZONTAL AND VERTICAL POSITIONS OF THE BODY

It will be noticed that the subjects employed in this series of tests are the same as those used in the visual memory tests. In fact, all subjects tested in visual memory were at the same time tested in strength of grip by the use of the hand dynamometer. The tests were so alternated with those of blood pressure, and heart-beat, and visual memory as to allow all the effects of fatigue from a single effort to pass away before the second effort was made. The general plan employed was to place the subject upon the Mosso instrument in the horizontal position, and after testing the heart-beat and blood pressure, to allow the subject to grip the dynamometer as strongly as he could, after which the visual memory tests were taken. By the time these were finished in the horizontal position, which usually occupied eight or ten minutes, and the subject was elevated to the vertical position, all signs of fatigue from the previous test had passed away and the second test could be taken. This method continued in as many series of tests as were taken for visual memory, and in most instances it will be found that the number of tests taken correspond exactly with the number taken for visual memory. In every case the subject was asked to take the dynamometer in his right hand, allowing the arm to rest on the Mosso instrument, and without moving other parts of the body, to grip it as strongly as possible. Since the hand and arm are in the same relative position to the body whether standing or lying down, theoretically, from the mere standpoint of position, no difference in the strength of the grip would be expected. However, the table indicates that subjects have a stronger grip in the vertical than in the horizontal position. The explanation is seemingly to be found in the fact that in the vertical posture, the blood pressure is generally higher and the muscular tonicity more easily maintained.

By referring to Table XV (next page), it is seen that only two subjects do better in the horizontal than in the vertical position. There are as many as thirteen who do practically the same in the two positions, there being only a slight advantage in favor of the vertical. But there are ten subjects who do very much better in the vertical, bring the comparative per cent. up to 105 in favor of the vertical position. This is rather a decided tendency. Indeed the two subjects who did poorer in the vertical are counted among those who did practically the same in the two positions, and it is possible that

if ten more experiments had been performed on these subjects an equal tendency might be found in the opposite direction. The mean strength of all subjects tested in the horizontal position is 57.2 with a mean variation of 2.6, while in the vertical position of the body, the mean strength of all the subjects is 60.3 with a mean variation of 6.2.

TABLE XV

A comparison of grip in the horizontal and vertical positions of the body by the use of the hand dynamometer.

Horizontal				Vertical			
Subject	Number of tests	M.	M.V.	Number of tests	M.	M.V.	Comparative per cents
H.	10	71.3	2.3	10	78.0	4.2	109%
B.	12	36.2	1.5	12	42.0	2.3	117%
S.	10	32.6	2.3	10	32.2	1.5	98%
S.'	10	53.2	2.1	10	54.8	2.7	103%
M.	12	52.3	2.6	12	56.2	3.1	107%
R.	12	68.4	3.5	12	75.3	2.8	110%
C.	15	61.1	2.3	15	71.3	3.5	118%
S."	10	69.1	3.5	10	70.2	2.1	102%
F.	12	56.2	2.7	12	57.2	1.2	102%
F.'	10	76.1	2.1	10	80.5	3.2	106%
G.	12	56.7	3.1	12	60.2	2.5	107%
L.	15	60.2	3.6	15	65.1	2.1	108%
A.	20	35.2	2.1	20	37.3	1.8	106%
C.'	10	62.3	3.1	10	64.4	2.8	103%
D.	10	33.2	3.2	10	40.4	3.7	121%
J.	12	63.7	1.4	12	67.2	4.3	105%
S.'''	10	37.2	2.6	10	38.2	2.7	103%
N.	15	48.2	3.4	15	49.1	1.8	102%
H.'	10	76.4	2.3	10	78.2	1.3	102%
H."	12	68.4	3.1	12	69.5	2.6	102%
M.'	15	59.2	2.5	15	63.7	2.3	108%
K.	10	30.4	1.5	10	29.6	2.6	97%
A.'	12	65.8	2.3	12	67.2	3.1	102%
L.'	10	68.2	1.4	10	71.2	3.2	104%
I.	12	61.2	3.1	12	65.8	1.4	107%
S.""	10	70.3	2.6	10	71.4	2.7	101%
P.	10	70.4	4.1	10	72.4	3.4	102%
		M. 57.2 M.V. 11.6	M. 2.6 M.V. .5		M. 60.3 M.V. 12.3	M. 2.6 M.V. .7	M. 105% M.V. 4.1%

It seems to the writer that this series of tests gives conclusive evidence that when the body is erect there is greater strength of the grip than when the body is in a reclining posture. This table, probably more than any other series of tests presented, shows clearly special adaptation for strength in the vertical position. The results of this series show too that the strength tests given in the gymnasiums are valid only when all subjects are required to maintain the body in precisely the same position for each of the tests.

CHAPTER XII

SOME ADDITIONAL DATA UPON THE PRECEDING RESULTS

In order to verify the results of the tests recorded in the preceding chapters, it was thought advisable to select four subjects who had not been employed in the previous experiments and take them through all the tests in precisely the same manner in which the original tests were made. It will be remembered that all the subjects used heretofore were those selected from the various departments of the university who were willing to give a little time to the investigation, and in consequence of this fact, the list of subjects is a very naive and irregular one. There was great difficulty in securing the same subjects for two consecutive series. The results attained are thus from groups of individuals varying materially from each other, both in size and psychological training. For this reason, it might reasonably be expected that while there is a certain validity in the result for this particular group, another group of individuals, having more training and being selected with special reference to this test, might show entirely different results. The writer, therefore, selected four men who were willing to serve as subjects in the following series: discrimination of pitch, tactile discrimination, visual memory, auditory memory, adding, tapping test, fatigue test, and grip. These subjects were not exactly naive, but had had a little experience in the methods of the psychological laboratory. Two were students in Teachers' College, Columbia University, and one a teacher in the New York City Schools. All had taken courses in psychology and were interested in the subject in the experimental field, but had done very little practical work. The results following are therefore results of practically naive subjects, but seem to the writer to have greater weight, because the same group of individuals is used for each series.

It does not seem necessary to explain the succeeding tables, for all the tests were taken in precisely the same manner as those described in the previous chapters. The same apparatus was used in every instance, and the same method of tabulating and recording. A comparison of the corresponding series of experiments shows that in general the results of the former tests are verified by those recorded in this chapter. It is true there is some little variation, but on the whole the results are the same in the various series. In order that the comparative results may be quickly and easily seen, the tables in this chapter will contain also the results found in the tables in the previous chapters.

ADDING

	Horizontal													Vertical													
		Time		Size of errors											Time		Size of errors										
Subject	Number of experiments	M.	M.V.	1	2	3	4	5	6	7	8	9	10	Number of experiments	M.	M.V.	1	2	3	4	5	6	7	8	9	10	Comparative per cents
M.	30	26.4	4.1	1— 1+	5+	1+							3+	30	28.3	5.1	1+ 2—	3+	1+	1+		1+				4+ 1—	107%
G.	20	19.3	3.7	2+ 2—	1+ 1—			1+					4+	20	21.6	4.1	3+ 1—	4+	2+	1+		1+				1+	111%
S.	24	5.1	7.2	2+ 1—	3+	1+		1+					1—	24	36.4	5.2	2+ 1+	3+	4+		1+		2+			1+	103%
A.	18	18.6	4.2	4+ 1—	1+	1+								18	17.9	5.3	5+ 2—	4+	1+	2+ 1—	1+					1+	96%
		M. 24.8 M.V. 5.9	M. 4.8 M.V. 1.2												M. 26.0 M.V. 6.3	M. 4.9 M.V. .4											M. 104% M.V. 4.7%
RESULTS BROUGHT FORWARD FROM TABLE IX																											
		M. 26.3 M.V. 8.7	M. 3.1 M.V. 1.2												M. 27.5 M.V. 9.4	M. 3.2 M.V. 1.1											M. 103% M.V. 4.8%

DISCRIMINATION OF PITCH

	Horizontal				Vertical				
Subject	Δ	Number of experi-ments	Per cent right	P.E.	Δ	Number of experi-ments	Per cent right	P.E.	Comparative per cents
M. G. S. A.	2 3 2 3	150 100 100 100	62 85 91 80	4.4 1.9 1.0 2.4	2 3 2 3	150 100 100 100	68 87 93 82	2.8 1.8 .9 2.2	64% 94% 90% 91%
				M. 2.4 M.V. .9				M. 1.9 M.V. .5	M. 85% M.V. 10%

RESULTS BROUGHT FORWARD FROM TABLE III

	M. 3.6 M.V. 1.9		M. 2.2 M.V. .8	M. 78% M V. 21%

TACTILE DISCRIMINATION

	Horizontal				Vertical				
Subject	Δ	Number of experi-ments	Per cent right	P.E.	Δ	Number of experi-ments	Per cent right	P.E.	Comparative per cents
M. G. S. A.	1 1 1 1	100 100 100 100	85 92 85 82	.6 .4 .6 .7	1 1 1 1	100 100 100 100	76 90 86 80	.9 .5 .6 .8	150% 125% 100% 114%
				M. .57 M.V. .09				M. .7 M.V. .15	M. 122% M.V 15%

RESULTS BROUGHT FORWARD FROM TABLE VI

	M. 1.16 M.V. .24		M. 1.7 M.V. .59	M. 146% M.V. 36%

VISUAL MEMORY

	Horizontal			Vertical				
Subject	Number of tests	Mean trials	Errors	Number of tests	Mean trials	Errors	Comparative per cents: Means	Comparative per cents: Errors
M.	14	8.7	362	14	8.9	521	102%	144%
G.	12	4.6	174	12	5.2	223	113%	128%
S.	15	5.4	211	5	5.3	263	98%	124%
A.	12	4.3	185	12	4.9	243	114%	131%
		M. 5.7 M.V. 1.7	M. 233 M.V. 64		M. 6.0 M.V. 1.3	M. 312 M.V. 104	M. 106% M.V. 6%	M. 132% M.V. 6%

RESULTS BROUGHT FORWARD FROM TABLE X

		M. 5.2 M.V. 1.5	M. 199 M.V. 66		M. 5.8 M.V. 1.3	M. 236 M.V. 58.		

AUDITORY MEMORY

	Horizontal			Vertical				
Subject	Number of tests	Mean trials	Errors	Number of tests	Mean trials	Errors	Comparative per cents: Means	Comparative per cents: Errors
M.	10	4.2	126	10	4.6	285	108%	226%
G.	12	3.6	172	12	3.9	196	108%	114%
S	14	5.9	295	14	6.4	372	108%	127%
A.	12	8.7	431	12	8.6	450	98%	104%
		M. 5.6 M.V. 1.7	M. 256 M.V. 107		M. 5.8 M.V. 1.6	M. 325 M.V. 85	M. 105% M.V. 4%	M. 142% M.V. 41%

RESULTS BROUGHT FORWARD FROM TABLE XII

		M. 6.3 M.V. 1.3	M. 227 M.V. 64		M. 7.3 M.V. 1.4	M. 250 M.V. 64		

TAPPING TEST

Subject	Horizontal: Number of tests	Horizontal: Time M.	Horizontal: Time M.V.	Vertical: Number of tests	Vertical: Time M.	Vertical: Time M.V.	Comparative per cents
M.	30	11.4	.6	30	11.2	.3	98%
G.	24	12.8	.7	24	12.1	.4	94%
S.	18	14.7	.6	18	13.8	.5	94%
A.	26	15.1	.8	26	14.4	.4	97%
		M. 13.5 M.V. 1.4	M. .67 M.V. .07		M. 12.8 M.V. 1.2	M. .4 M.V. .05	M. 95% M.V. 2+%

RESULTS BROUGHT FORWARD FROM TABLE XIII

		M. 14.2 M.V. 1.5	M. .8 M.V. .5		M. 13.6 M.V. 1.59	M. .7 M.V. .2	M. 95.7% M.V. 3.2%

FATIGUE

Subject	Horizontal: No. of tests	Horizontal: Fatigue	Horizontal: M.V.	Vertical: Fatigue	Vertical: No. of tests	Vertical: M.V.	Comparative per cents
M.	12	92.7	3.4	99.5	12	3.2	107%
G.	15	79.2	8.6	87.6	15	9.2	110%
S.	12	84.3	4.7	89.5	12	3.8	106%
A.	20	74.2	11.6	80.2	20	8.7	108%
		M. 82.6 M.V. 5.9	M. 7.07 M.V. 3.02	M. 89.2 M.V. 5.3	M.	M. 6.2 M.V. 2.7	M. 107.7% M.V. 1.2%

RESULTS BROUGHT FORWARD FROM TABLE XIV

		M. 78.8 M.V. 7.3	M. 5.5 M.V. 1.2	M. 82.8 M.V. 6.6		M. 5.7 M.V. 1.1	M. 105% M.V. 2.2%

GRIP

Horizontal				Vertical			
Subject	Number of tests	M.	M.V.	Number of tests	M.	M.V.	Comparative per cents
M. G. S. A.	10 12 15 12	64.4 49.2 54.6 61.2	5.2 4.6 5.8 4.7	10 12 15 12	68.3 52.3 53.2 65.3	4.1 5 1 7.6 9.4	106% 107% 98% 106%
		M. 57.3 M.V. 5.4	M. 5.0 M.V. .4		M. 59.7 M.V. 7.0	M. 6.5 M.V. 1.9	M. 104% M.V. 3%
RESULTS BROUGHT FORWARD FROM TABLE XV							
		M. 57.2 M.V. 11.6	M. 2.6 M.V. .5		M. 60.3 M.V. 12.3	M. 2.6 M.V. .7	M 105% M V. 4.1%

Summing up the results of all the tests made in the various series, there is no doubt that for the subjects tested, pitch is discriminated better in the vertical than in the horizontal position; tactile discrimination is slightly more acute in the horizontal than in the vertical; visual memory is both more rapid and subject to fewer errors in the horizontal than in the vertical position; auditory memory shows the same result as the visual memory; adding can be done more rapidly and with greater precision in the horizontal posture; subjects show greater signs of fatigue in the horizontal than in the vertical posture; a greater number of taps per minute can be made in the vertical than in the horizontal position; and the vertical position is favorable to the strength of grip.

ACKNOWLEDGMENTS

The greater part of the experimental work of this investigation was carried on in the Psychological Laboratory of Columbia University. The writer is indebted to Professor J. McKeen Cattell and to Professor R. S. Woodworth for many courtesies, and valuable suggestions in the conducting of the numerous series of tests. He also wishes to express his thanks and obligations to Professor E. L. Thorndike, of Teachers' College, for valuable suggestions upon some parts of the statistical work involved in the dissertation. He is indebted to all who served as subjects throughout the long series of tests, to the assistants in the Psychological Laboratory, Dr. Vivian A. C. Henmon, Mr. Stevenson Smith, and Mr. Hamilton, and to the fellow in psychology, Dr. F. Lyman Wells, and all special students in psychology who gave much time for the carrying on of the work; also to Mr. W. H. Smith, the mechanician in the Laboratory. These subjects have records appearing in many of the tables throughout the investigation, and the writer feels under the deepest obligations to them. I am also indebted to Miss Lila London, Professor of Mathematics in the State Female Normal School, Farmville, Va., and to Dr. J. F. Messenger, Professor of Psychology and Education, for valuable suggestions and corrections in the manuscript, and reading of proof.